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CONTENTS

NULLIUS IN VERBA: SCIENCE VS PSEUDO-SCIENCE/FRINGE SCIENCE

Boris Aberšek
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The Royal Society's[1] motto 'Nullius in verba' is taken to mean 'take nobody's word for it'. It is an expression of the determination of Fellows to withstand the domination of authority and to verify all statements by an appeal to facts determined by experiment.
Royal Society

The explosion of disinformation about global warming and other ecological problems could be called an *infodemic[2],* which is the term used by WHO to describe today's pandemic situation. An infodemic means too much information, however, its importance can also be passed on to environmental problems. It causes confusion and risk-taking behaviors that can harm the health of our planet. It also leads to mistrust in authorities and undermines the public response. An infodemic can intensify or lengthen outbreaks when people are unsure about what they need to do, for example, to protect our environment. With growing digitization – an expansion of social media and internet use – information can spread more rapidly. This can help to more quickly fill information voids but can also amplify harmful messages.

Infodemic management is the systematic use of *risk- and evidence-based analysis* and approaches to manage the infodemic and reduce its impact on our environment. Infodemic management in relation to ecological problems focuses on enabling good practices through four types of activities:

- Listening to community concerns and questions.
- Promoting understanding of risk and health expert advice.
- Strengthening resilience to misinformation.
- Engaging and empowering communities to take positive action.

Infodemic management is widely known, but much less discussed is the role of *ostensible "experts"* or fringe scientists in perpetuating dangerous fictions. Since the dawn of the crisis, a disconcerting number of eminently qualified (pseudo)scientists and physicians have propagated falsehoods across social media, elevating themselves to the status of gurus in order to lend a veneer of seeming scientific legitimacy to empty, dangerous claims. And

1 https://royalsociety.org/about-us/history/
2 An *infodemic* is too much information including false or misleading information in digital and physical environments during a disease outbreak. See: https://www.who.int/health-topics/infodemic#tab=tab_1

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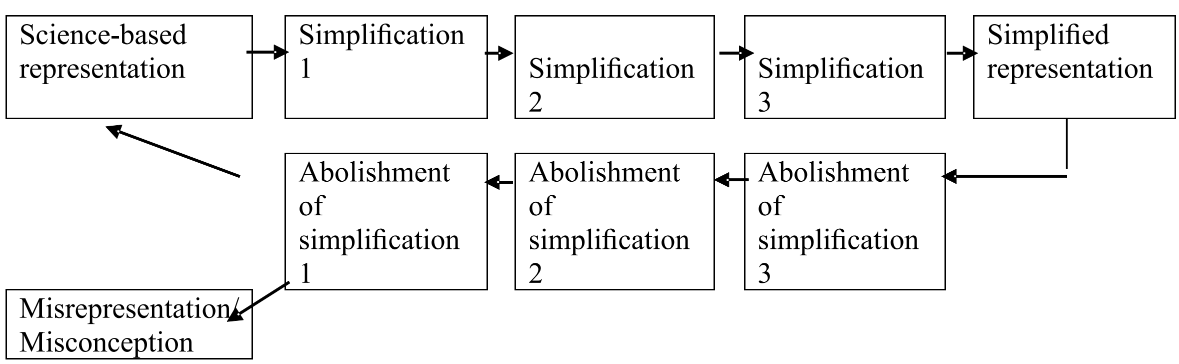
these bogus claims, like their pathological namesake, have gone uncontrollably viral. These fringe pseudoscientists are lauded as experts unafraid to speak truth to power. But it is crucial to note that these individuals, for all their formal credentials, extol a narrative completely at odds with reality, readily refuted by public bodies the world over. These pseudoscientific, conspiratorial claims are archetypal arguments from authority, where a perceived expert's support is used to justify positions unsupported by data. Scientific claims do not derive their authority by virtue of coming from scientists but from the weight of the evidence behind them. Pseudoscience, by contrast, tends to focus on ostensible gurus **(**see *Kanneman system 1***)** rather than a *consensus opinion* **(**see *Kanneman system 2***)** (Kanneman, 2011). The only authority a scientist can ever truly invoke is a reflected one, dependent on accurately representing the evidence base. If they embrace fringe positions and jettison the principles of scientific skepticism, then their qualifications, education, and prestige mean absolutely nothing (Grimes, 2021).

In order to justify facts, scientists (unfortunately) use complex scientific methods, which are largely incomprehensible to most people. Meanwhile, pseudo-scientists use methods that are closer and more unambiguous to the everyman. Real science should be more approachable to the everyman, it should use such methods and arguments, which would be easier for people to understand, while at the same time not crossing the line of dismissing the accuracy and, above all, the reliability of what is being said, at the expense of improving intelligibility. If, while generalizing, we omit the less relevant and difficult-to-understand arguments and generalize to the level of the general population's understanding, then – as we reverse the generalization, adding more or less relevant data, which was omitted in the process of simplification – we should always be able to return to the starting point of the problem at hand, to the same complex scientific explanation.

In essence, the simplification process must be reversible, which means that a reverse process will bring us back to the starting point, which is symbolically shown in Figure 1.

Figure 1
The Simplification Principle (Aberšek, 2015, a,b)



The Difference between COVID-19 and Environmental Problems

Though people live in the here-and-now, they have the capacity to think about future events, remote places, distant others, and alternative realities. This ability to think about events that extend beyond the immediate context is one that many might take for granted. *Construal level theory (CLT)* attempts to explain how people accomplish this remarkable feat. Central to understanding CLT is the idea of *psychological distance* (Trope & Liberman, 2010). *Construal level theory (CLT)* is a theory in social psychology that describes the relationship between psychological distance and the extent to which people's thinking (e.g., about objects and events) is *abstract* or *concrete*. The general idea is that the more distant an object is from the individual, the more abstract it will be thought of, while the closer the object is, the more concretely it will be thought of.

Let us provide a topical example of a low level construal, i.e., when people think more about the context-specific features: COVID-19. We are all aware that we will have to find a solution as soon as possible, and the only currently logical solution is vaccination. With this in mind, scientists have joined forces and developed a vaccine in less than a year's time. The process of vaccine development and adoption, which in recent history took considerably longer, several years, now took less than a year. This solution, which may be more or less optimal, reliable and hazardous,

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has withstood the anti-vaccine sentiment of numerous and various groups, and the vast majority of people have decided to get vaccinated, which makes perfect sense, considering the state of chaos in which we currently are.

High level construal means that the more distant an object is from the individual, the more abstractly it will be thought of. With long-term abstract thinking, many of the things we are aware of fall away, we negate time, we are not ready to make compromises, we doubt the proposed solutions, or even deny the existence of a problem (for example, environmental issues), and there is always the question of whom we can trust. The foundation of trust is based upon the realization that various "non-scientists and pseudo-scientists" are exploiting science for their own purposes, thereby destroying trust in science. The rise of pseudo-experts is perhaps symptomatic of a change in how we access information. As we become curators of our own media, the traditional gatekeepers and fact-checkers once implicit in most reporting have been increasingly sidelined. This in turn has made us more polarized and reduced our ability to differentiate fact from opinion. *Motivated reasoning*[3], our human bias towards cherry-picking only arguments that chime with that we wish were true, most certainly plays a role. The impositions of global warming and other ecological problems are manifold; it is not surprising that fringe scientists are inevitably invoked as sources for those with strong feelings against, for example, measures to reduce greenhouse emissions. Even if we are not ideologically predisposed to such positions, these claims undermine public understanding, blurring perceptions of scientific consensus, nudging us collectively towards fear and distrust.

Understanding the process of science can protect people against misinformation – or at least we hope so. One of the most intriguing stages in the process of science is noticing when something is ... weird. 2020 has been a historic year – and mostly not in a good way. Among many things, we saw a historic level of disregard of scientific advice with respect to the COVID-19 virus. But while the events of 2020 may feel unprecedented, the social pattern of rejecting scientific evidence did not suddenly appear this year. There was never any good scientific reason for rejecting the expert advice on COVID, just as there has never been any good scientific reason for doubting that humans evolved, that vaccines save lives, and that greenhouse gases are driving disruptive climate change.

For all their qualifications, fringe scientists fail this basic tenet of science, as they are united in their willingness to embrace conspiracy theory when their claims are refuted. Lack of evidence for their position is airily dismissed as a cover-up by everyone from authorities at a global level, to the entire ecological establishment. But this performative outrage is so much sound and fury to distract from the inescapable reality that their positions are completely contradicted by the overwhelming weight of scientific evidence. This is scientifically reprehensible, and staggeringly irresponsible, conduct.

Potential Solutions

In recent decades, the gap between scientists, pseudo-scientists, influencers, and politicians has become increasingly clear. The question of whom one can trust, whom one can believe, is becoming ever more common. The solutions to this problem need to be long-term and systematic and developed especially by means of:

- developing critical thinking and critical decision-making of the whole society (or at least a large part of it, as true believers can never be convinced by the power of arguments),
- facts (logical argumentation, good science) versus pseudo-facts (bad science) arising from the problem of interpretation (System 1 or System 2),
- a strategic separation of truth from potential lies (unverified or poorly verified facts) or actual lies (deception and manipulation), which are a result of using pseudo-scientific methods and misleading use of various statistical explanations and shortcuts.

It is entirely understandable that many are left confused and uneasy by the vocal assertions of fringe figures, but the onus of proof is always on those making grand claims. The history of science is littered with the hubris of the arrogant and misguided, and mere credentials are no impediment to being wrong; only evidence truly matters. When confronted with the pronouncement of fringe figures, the motto of the Royal Society should always be at the forefront of our mind: Nullius in Verba (take nobody's word for it) (Grimes, 2021).

3 *Motivated* reasoning is a phenomenon studied in cognitive science and social psychology that uses emotionally biased reasoning to produce justifications or make decisions that are most desired rather than those that accurately reflect the evidence, while still reducing cognitive dissonance.

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DEVELOPMENT OF A CHILDREN ENTREPRENEURIAL SCIENCE THINKING TEST FOR STEM EDUCATION

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Nyet Moi Siew

Abstract. *There are limited research studies about the development of test instrument to assess the level of entrepreneurial thinking among children in STEM education. The purpose of this research was to develop an Entrepreneurial Science Thinking Test (ESTT) for primary school children in STEM Education and evaluate its validity and reliability. The ESTT was developed using experiential learning theory which comprised of five constructs, namely Observation, New Ideas, Innovation, Creativity, and Value. The ESTT consisted of ten open-ended question items that require children to answer questions in statements and draw sketches of ideas. The evaluation was conducted to determine the reliability and validity of ESTT which involved five subject matter experts and 166 11-year-old fifth graders from five urban schools in Sabah, Malaysia. The data obtained from fifth graders were computed using WINSTEPS software version 3.73 and analysed using the Rasch measurement model. The results indicated a high acceptable content validity and construct validity, high internal consistency, and excellent item reliability and item separation. Through item fit analysis, all items were retained. The finding established the reliability and validity of the ESTT and would therefore represent a valid and highly reliable instrument for measuring entrepreneurial science thinking among fifth graders in STEM Education.*

Keywords: *experiential learning theory, science entrepreneurial thinking, validity and reliability, STEM education*

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Introduction

Entrepreneurial thinking (ET) is one of many critical skills that 21st century learners require in facing an increasingly competitive world. ET has the potential to enrich human capital in gaining innovative knowledge, new revolutionary ideas, and strong ethical standards (Bacigalupo et al., 2016). ET can be defined as a cognitive situation that seeks creative and innovative ideas as well as opportunities (Krueger, 2005). ET is not an ability that needs to be mastered in order to become a mere entrepreneur, but it is a soft skill that is required to enhance human growth, meet the job market and improve productivity (Bacigalupo et al., 2016). In producing learners who can master the characteristics and ethics of entrepreneurship, handle existing resources well and face future challenges efficiently, this ET is very important (Edwards-Schachter et al., 2015). Learners can be more analytical, creative, and inventive thinkers, successful in communication, and ethical workers with these skills (Lekashvili, 2013).

The importance of ET for supplying skilled workers who can communicate different soft skills in Science, Technology, Engineering and Mathematics (STEM) fields has been acknowledged by some countries in their 21st century curricula (Borowczak, 2015). However, integrating ET is still not widespread in STEM education. Eltanahy et al. (2020) stressed the importance of applying ET in STEM learning to raise the awareness of STEM design among learners and inspire them to be more entrepreneurial. Learners studying STEM without ET skills are less likely to have the capability to determine the value of products derived from the socio-economic aspects of society. This is significant because learners are currently showing high trends (61.4%) towards STEM-based careers (Hatisaru, 2021). Swartz and McGuinness (2014) stressed that thinking skills need to be explicitly taught in curricula, while Gunawan & Shieh (2020) recommended that ET is integrated into any STEM curriculum to produce a significant effect on learning.

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Realizing the need for entrepreneurial thinking in STEM, the importance of ET began to be examined by some Malaysian local scholars. Buang et al. (2009) have proposed a combination of science process skills and entrepreneurial thinking known as Entrepreneurial Science Thinking (EST). This concept integrates problem-solving ideas and entrepreneurial elements to train learners to search for thorough ideas in solving a problem creatively (Syukri et al., 2013b). However, there is little research on the development of test instruments to assess the level of entrepreneurial science thinking among primary school children in STEM education. It is therefore important to develop an ET test for STEM education to ensure that ET is nurtured in STEM education from primary school level (Liu & Zhi, 2010; Menzies, 2012; Sheehan et al., 2018). The Entrepreneurship Science Thinking Test (ESTT) was developed in line with this to assess entrepreneurial science thinking among fifth graders in STEM education.

Research Problem

Entrepreneurial science thinking begins with an important basic science skill which is the skill of creating (Daniel, 2016; Neck & Greene, 2011). In the concept of classroom assessment in Malaysian schools, learners with good creating skills can achieve the mastery level six (ML6). However, based on the Classroom Assessment Mastery Achievement Report (Tawau District Education Office, 2019), the number of tenth graders who achieved ML6 for Science subjects was only 4%, far behind when compared to ML5 (23.82%) and ML4 (44.25%).

Furthermore, based on the PISA Report 2018 (Schleicher, 2019), the average score of Malaysian ninth graders in terms of science literacy is only 438, below the international average score of 489. This is a disconcerting scenario because the nation holds high aspirations to achieve a nation of creators by 2030. Therefore, it is obvious that entrepreneurial science thinking needs to be infused from the primary school level to better develop the children's science literacy, critical thinking, and reasoning skills (Hoachlander & Yanofsky, 2011; National Research Council, 2011).

The application of entrepreneurial science thinking in STEM Education is now considered significant in preparing children today to venture into STEM-related careers (Dabney et al., 2012; Sadler et al., 2012; Wyss et al., 2012). Such application will encourage children to solve challenging and meaningful daily problems as well as improve their cognitive reasoning skills (Hunter et al., 2016). In addition, entrepreneurial science thinking opens up space for learners to think more broadly to explore new ideas in STEM-based problems (English et al., 2017). Children with entrepreneurial science thinking are able to learn STEM in real context and develop their STEM literacy in order to succeed in the modern economic era (Tsupros et al., 2009). In fact, they are also able to face the challenges of daily life related to the field of STEM (Bybee, 2013). In addition, entrepreneurial science thinking also encourages children to improve Science literacy (McDonald, 2016) and engineering design skills emphasized in STEM (Afriana et al., 2016; Jin & Bierma, 2013; Kennedy & Odell, 2014; Kuenzi, 2011; Zollman, 2012). It is clear that the application of entrepreneurial science thinking in STEM Education needs to be implemented explicitly starting at a lower school level to achieve the country's desire to produce STEM-skilled human capital capable of solving global problems, making decisions, and innovating creations for the benefit of future societies.

Although entrepreneurial thinking has been introduced in the Malaysian curriculum, the development of instruments that measure the level of entrepreneurial science thinking among primary school children in STEM education is not yet widespread (Buang et al., 2009; Syukri et al., 2013a). Instruments that have been developed previously only measure the readiness of the integration of entrepreneurial science thinking (Ishak et al., 2014) and teacher pedagogical knowledge in teaching entrepreneurial science thinking (Syukri et al., 2013b).

Li et al. (2016) developed an instrument for measuring entrepreneurial thinking among engineering students. The instrument was developed based on Kern Entrepreneurial Engineering Network (KEEN) framework that is specialised in the context of engineering. The instrument focuses on three aspects, namely Curiosity, Connections, and Creating Value. The instrument reduced its items from 37 items to 29 items after the validity and reliability analysis using exploratory factor analysis. Unfortunately, the items do not reflect the development of new ideas and positive values in students' creation. Bolton and Lane (2012) developed an Individual Entrepreneurial Orientation (IEO) instrument for testing entrepreneurial thinking among 1,100 university students. By using exploratory factor analysis, the instrument was found reliable and valid in assessing three of the five dimensions: innovativeness, risk-taking, and proactiveness. However, the measurements are comparatively restricted in these three dimensions. The extent to which the students' observation of current materials and

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designs, as well as the contribution of inventions to society, was not assessed. Schelfhout et al. (2016) constructed an instrument to assess entrepreneurial competence using a behavioural indicator scale, in addition to measuring entrepreneurial thinking. The instrument was developed with 11 sub-competencies that assess high school students' competence and entrepreneurial thinking.

To sum up, most instruments constructed for measuring entrepreneurial thinking are appropriate for learners of higher education and secondary school. There are few and limited instruments targeting entrepreneurial science thinking for primary school children in STEM education. Hence, an instrument for assessing entrepreneurial science thinking for STEM Education needs to be developed and introduced at a lower school level. In line with this, the Entrepreneurship Science Thinking Test (ESTT) was developed, and its validity and reliability were assessed to ensure its usability in measuring entrepreneurial science thinking among fifth graders in STEM education.

Literature Review

Science Entrepreneurial Thinking

The concept of Entrepreneurial Science Thinking (EST) is a notion of science teaching and learning to produce learners who are equipped with entrepreneurial thinking (Syukri et al., 2013a). EST is referred to as design thinking skills based on scientific knowledge and entrepreneurial orientation (Buang et al., 2009). Buang et al. (2009) proposed the Entrepreneurial Science Thinking Model (ESTM) which provided the theoretical model of entrepreneurial thinking in this study. ESTM consisted of five constructs namely Observation, New Ideas, Innovation, Creativity, and Value as described below.

Observation

The observation construct refers to the activity of observing various phenomena found in the environment that is related to the concept of science (Buang et al., 2009). The observation construct, as described in this study, is the activity of making observations in a planned and purposeful manner. Learners make observations about the appropriate materials and designs used to make a new product.

New Ideas

There is a need for new ideas through phenomena that have been observed in the form of ideas, systems, models, designs, or products (Buang et al., 2009). In this research, the new ideas construct suggests that learners generate ideas by continuously thinking about the use of materials and the design of materials used in new products to seek uniqueness.

Innovation

Buang et al. (2009) stressed that the innovation construct refers to the activity of learners selecting some ideas that can be improved and evaluating the selected ideas. In this research, the innovation construct allows students to select ideas that can be modified or improved from the previous steps. In the future, the selection of these ideas for change helps in creating product designs. Learners then need to evaluate the ideas by specifying the reasons for the idea they selected.

Creativity

The definition of creativity can be applied in a concentrated way as the task of creating new ideas (Buang et al., 2009). In this study, the creativity construct refers to the task of reinforcing and evolving ideas in a concentrated way. Learners express their new ideas by sketching designs, labelling, and building product design models. Learners are then asked to state the name of the product, the price offered and the target group of buyers for the product produced.

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Value

Value constructs refer to activities to ensure that the ideas or products produced are beneficial to society. In terms of cost savings, product function as well as values and ethics in product invention, learners need to state the benefits of their products. This is to cultivate values such as love of the environment and the practice of using sustainable materials in the production of products for the community. Learners then present their model in front of the class and present the benefits of their products.

Experiential Learning Theory in ESTT Development

Kolb (1984)'s experiential learning theory defines learning as "the process whereby knowledge is created through the transformation of experience" (p. 41). Kolb proposed that learners learn through a circle of experiences that lead to observations and reflections. These reflections are applied to prior understanding and converted into abstract concepts or theories, resulting in forms and behaviours to adapt to new experiences that can be tested and explored. As claimed by Gemmell and Kolb (2013), experiential learning theory is in line with the concept of entrepreneurial science thinking which is based on learning through reflection and experience. Entrepreneurial science thinking needs to go through social and cognitive processes where learners develop new ideas and transform those ideas so that they can be used in the market and society (Gemmell et al., 2012). Thus, this theory provided the theoretical framework of ESTT development where learners use their experience to solve consumer problems and produce innovative products and services for the benefit of society.

Kolb (1984) further reiterated that individuals progress through the four stages of the learning cycle that are interconnected, namely concrete experience, reflective observation, abstract conception, and active experimentation (Figure 1). During the stage of concrete experience, learners are involved with new experiences which become the basis of observation. Next, in reflective observation, individuals reflect on their observation and begin to construct a general theory of what this information means. In the next step of abstract conceptualization, learners organize information systematically and logically into concepts, theories, and ideas. Finally, during the active experimentation stage, learners test the implications of these concepts in new situations. At this stage, learners are able to see things from various perspectives and act creatively and innovatively. The process once again returns to the first stage of the experience process.

The learning process of Kolb (1984)'s theory is in line with ESTT development, which encourages learners to experience the phases of Observation, New Ideas, Innovation, Creativity, and Values. Learners were exposed to issues through concrete experiences that would lead to the emergence of various ideas, which is in line with Observation in ESTT. This process leads to reflective thinking where learners obtain ideas and inspiration to invent products that could help in problem-solving. Hence, the reflective thinking stage is in line with New Ideas in ESTT. In the abstract conceptual stage, learners began to organize ideas and translate ideas in the form of prototype sketches. This is where innovation and creativity in ESTT take place. At this stage, through the experience they went through, learners invent their prototype. Carlsson et al. (1976) explained that the process of implementing solutions to issues would be carried out during the stage of active experimentation. Accordingly, learners evaluated their products by ensuring that the products invented could solve issues and benefit the users. As explained by Krakauer et al. (2017), the stage of active experimentation is the stage where learners relate their perceptions to the actual context. In this study, the actual context refers to the context of society where learners applied their STEM knowledge and experience in inventing the products that would benefit society. This stage represents the Value construct of ESTT.

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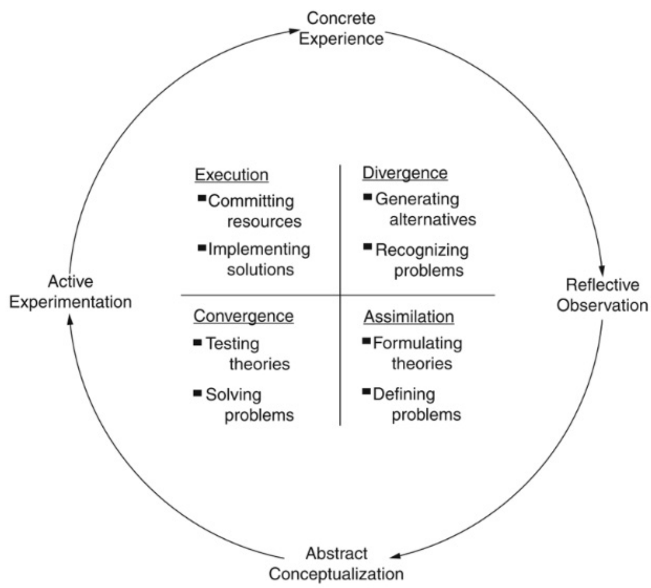
Figure 1
Learning cycle in Kolb's Experiential Learning Theory (1984)



Rasch Measurement Model

The Rasch Measurement Model (RMM) is an efficient solution for the development of in-depth statistics to provide high validity and reliability of ESTT instrument (Bond & Fox, 2015). RMM analyses each respondent's ability to respond to the instrument and measures the difficulty of each item in the instrument (Wolins et al., 1982). RMM is also able to assess latent characteristics, such as human thoughts and emotions (Aziz et al., 2015).

The RMM built on the basis of Item Response Theory is among the adequate statistical models as it can calculate the item's difficulty and the individual's ability to be evaluated at the same time (Deane et al., 2016). As a result, the RMM was able to classify the items and person validity and reliability. Furthermore, Rasch analysis can be used in terms of item polarity, item and respondent misfit, as well as dimensionality, to perform construct validity.

While Rasch analysis can take a longer process than conventional analysis, Rasch analysis may offer a deeper understanding of the instrument's strengths and shortcomings (Boone & Scantlebury, 2005). Bond and Fox (2007) claimed that RMM, by statistical analysis, is an efficient solution for developing highly valid and reliable instruments. The researchers used Rasch analysis to assess the validity and reliability of the ESTT instrument based on these specified strengths.

Research Focus

The main focus of this research was to develop an instrument on entrepreneurial science thinking in STEM Education for 11-year-old children in primary schools. Validity and reliability are two important factors to consider when developing an instrument. Hence for the need to develop a valid and reliable tool, Rasch analysis was used to examine the validity and reliability of ESTT.

Research Aim and Questions

This research was aimed to develop a valid and reliable instrument for assessing entrepreneurial science thinking in STEM Education among fifth graders using the Rasch Measurement Model. There were three research questions guiding this research:

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Q1: Is ESTT feasible in assessing entrepreneurial science thinking among fifth graders in STEM Education?

Q2: How valid is ESTT in assessing fifth graders' science entrepreneurial thinking in STEM Education based on: 1) Person fit statistics; 2) Item fit statistics; 3) Item Polarity; and 4) Confirmation of unidimensionality?

Q3: How reliable is ESTT in assessing the entrepreneurial science thinking in STEM Education among fifth graders according to: 1) KR-20 Cronbach's coefficient alpha; 2) Person and item reliability indices?

Research Methodology

Research Design

A survey design using a test instrument was employed to obtain data on fifth graders' entrepreneurship thinking level. In education, a survey research design is well established as it can analyse topics and constructs efficiently and economically (Creswell & Creswell, 2017). The data gathered from the ESTT instrument was focused on the fifth graders' experiences of integrating the entrepreneurship elements in science project-based learning. This research was carried out between November and December 2019.

Research Sample

The ESTT was distributed to 166 samples that were chosen randomly from five primary schools in the Tawau district, Sabah, Malaysia. A sample size with the range of 108-243 is wide enough to have 99% confidence that the item difficulty can be measured within ± 1⁄2 logit of its stable value (Linacre, 1994). The research sample had a similar background where the selected schools were grouped in urban school clusters. The sample consisted of 87 girls (52.4%) and 79 boys (47.6%) aged between 10 to 11 years. Approximately 60% of parents were government employees, while 40% were working in the private and industry sectors.

Ethical Considerations

Written consent was obtained from the parents and school principals prior to the administration of ESTT. Initially, an outline of the intent of the ESTT which was to measure the level of entrepreneurial science thinking was meted out. The consent letter detailed the fifth graders' involvement in the research and the parents' consent reflecting their understanding of the research purpose. All the fifth graders were assured of the confidentiality of their responses and complete anonymity. Fifth graders were also informed that anyone could withdraw from the research without penalty. A follow-up briefing session was then carried out to explain the guidelines and procedures for answering questions in ESTT.

Administration of ESTT

Each fifth grader was asked to read the instructions carefully before answering the ESTT according to their respective knowledge without the help of other children. Fifth graders relate current information, insights, and experiences to the scientific principles and entrepreneurial aspects surrounding them throughout answering questions, such as building materials, the use of construction materials, design, uniqueness of an invention, and the impact of an invention on society. Fifth graders were given an hour to think and articulate their responses. Open questions were given according to the construct and fifth graders were required to answer the questions in the order of the constructs. The answers were collected and reviewed in advance to ensure the fifth graders followed the correct instructions and provided complete answers before the data are analysed using WINSTEPS software version 3.73.

Instrumentation

Entrepreneurial science thinking is the ability to create and make improvements to a product, idea, or process so that the product has added value from the social and economic aspects. In this regard, the relationship of sci-

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ence concepts acquired in the classroom and the ability of teachers in nurturing EST triggers innovation to adapt to situations that occur and are needed in the daily life of children (Venuvinod & Sun, 2002). This concept was used when developing the question items in the Entrepreneurial Science Thinking Test (ESTT).

Open-ended questions were used in measuring the entrepreneurial science thinking of each individual. The use of open-ended questions can help in obtaining variations in respondents' ideas (Chen et al., 2020), provide an overview of respondents' level of knowledge (Clarke & Holt, 2019), and help researchers identify misconceptions among respondents (Schuetz, 2010). Researchers constructed open-ended questions based on the five constructs in EST (Buang et al., 2009) which are Observation, New Ideas, Innovation, Creativity, and Value.

The ESTT consisted of ten open-ended question items that require fifth graders to answer questions in statements and draw sketches of ideas. Question items were developed by referring to the content of Standard Documents of Curriculum and Assessment (DSKP) for Year Five Science under the themes of Physical Science as well as Technology and Sustainable Life (Curriculum Development Division, 2019, p. 55-68). The main question asked fifth graders to produce cell phone designs for the use of the future community. The context of cell phone usage was chosen because it is one of the criteria in DSKP under the theme of Physical Science. Fifth graders were then given a stimulus picture and ten question items. Items were arranged according to the group of constructs to enable fifth graders to organize their answers which then lead them to Entrepreneurial Science Thinking. Table 1 shows the constructs of the Entrepreneurial Science Thinking Test (ESTT) for STEM Education.

Table 1
Items for ESTT by Construct

Construct	Definition	Item No.	Item statement
Observation	Make observations in a planned and purposeful manner.	1a	State the materials used to make cell phones.
		1b	State the design of a cell phone that you can observe.
New Ideas	Generate ideas by looking for uniqueness	2a	Explain the advantages of using the materials you mentioned to build the cell phone.
		2b	Explain the advantages of using the cell phone design you mentioned.
Innovation	Select ideas that can be improved and evaluate those ideas	3a	Based on the ideas you have stated in question 2, select three (3) ideas that you can improve to produce future cell phones.
		3b	Why did you choose the above ideas? Give three (3) reasons.
Creativity	Strengthen and improve ideas in a focused way	4a	Reinforce and improve the three (3) ideas you have chosen for the creation of new cell phones for future community use. Sketch and label new features on your model in the space provided.
		4b	Complete details about your product by stating the product name, price offered and target group of buyers.
Value	Ensure that the ideas or products produced are beneficial to the community	5a	State the benefits of your product to the community in terms of cost savings and product functionality.
		5b	State the benefits of your product to the community in terms of values and ethics in product creation.

Children were required to make observations in a prepared and purposeful way in the Observation Construct. The first item required the children to state the materials used to make a cell phone, whilst the second item required the children to state the cell phone design. Children were required to produce ideas relevant to individuality in the creation of New Ideas. By specifying the benefits of utilising the products and design requirements in the observation stage, children had to search for uniqueness or benefits. The fifth item in the Innovation Construct instructed children to choose three ideas that could be augmented and updated in order to create potential cell phones, while the sixth item requested children to state the reasons for choosing the ideas mentioned. The Creativity Construct allows children to validate and strengthen concepts in a focused way. The seventh item centred on children strengthening and improving the concepts chosen for the development of new cell phones. They were requested in this item to draw and mark new features on the model they made. Next by specifying the name of the product, the price available, and the target category of purchasers, the eighth item advised children to complete the details of the product they had made. Finally, the Value Construct was where children wanted to ensure that

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the products would help the society. The ninth and tenth items allowed children to state the advantages in terms of cost savings and include terms of values and ethics in product development, respectively.

The time allocation for answering all the items was 60 minutes. The scoring rubric for the Entrepreneurial Science Thinking Test construct was adapted from Ho et al. (2013). There is a minimum score of 0 and a maximum score of three for each item given in the test. Based on the child's response, each score was rated from 0 to 3 points. An example of a scoring rubric according to children's response for one of the constructs in ESTT is shown in Table 2.

Table 2
An Example of the Scoring Rubric according to Children' Response in ESTT

Construct	Ability	Scoring rubric	Levels and Scores
3. Innovation (Select ideas that can be improved and evaluate those ideas)	3.2 Make an evaluation of the ideas that have been selected.	3.2.4 Children can provide three (3) factors in the selection of ideas.	Level 4 3 marks
		3.2.3 Children can give two (2) factors in the selection of ideas.	Level 3 2 marks
		3.2.2 Children can provide one (1) factor in the selection of ideas.	Level 2 1 mark
		3.2.1 Children cannot give one (1) factor in the selection of ideas.	Level 1 0 mark
	3.1 Choose ideas that can be improved to produce new inventions.	3.1.4 Children can choose three (3) ideas	Level 4 3 marks
		3.1.3 Children can choose two (2) ideas	Level 3 2 marks
		3.1.2 Children can choose one (1) idea	Level 2 1 mark
		3.1.1 Children cannot choose one (1) idea	Level 1 0 mark

Source: Ho et al. (2013)

Data Analysis

The data of the research were analysed to determine the content and construct validity. To determine the value of content validity agreement, the researchers used the Content Validation Index (CVI). CVI provides an average rating of scores for all items evaluated by an expert. A CVI value can be computed for each item on a scale (I-CVI) as well as for the overall scale (S-CVI). Davis (1992) pointed out that for a newly designed instrument, the usual CVI value obtained is .80. For cases with content validation requiring three or more experts, Polit et al. (2017) recommended a rating of .78 and above for I-CVI and a minimum S-CVI of .80 for the averaging approach.

$$\text{Item Content Validation Index (I-CVI)} = \frac{\text{Total of experts in agreement}}{\text{Total of experts}}$$

$$\text{Scale Content Validation Index/Average (S-CVI/Ave)} = \frac{\text{Total I-CVI for each item on the scale}}{\text{Total of items}}$$

For assessing construct validity and item reliability, WINSTEPS software version 3.73 was used. This ensured the instrument's quality and the accuracy of the data obtained by the researcher before the instrument was used in actual research. The first analysis was conducted via a person fit analysis which was based on the values of 'MEASURE', MNSQ Outfit and ZSTD Outfit (Edwards & Alcock, 2010). Nevin et al. (2015) asserted that if the ZSTD Outfit value exceeds 2.0 and the MEASURE value is high, there is a probability that excellent learners would not carefully answer the easy items. If the ZSTD Outfit value exceeds 2.0 but the MEASURE value is low, it is likely that

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low-ability learners would be able to answer difficult items correctly. Therefore, unfit respondents will be eliminated to increase the validity of the instrument (Lamoureux et al. 2008).

For the item fit analysis, Boone et al. (2014) as well as Bond and Fox (2015) proposed three criteria namely, Outfit Mean Square Values (MNSQ), Outfit Z-Standardised Values (ZSTD) and Point Measure Correlation (PTMEA-CORR). The MNSQ Outfit value informs the researcher about the item fit in the measurement while the PTMEA-CORR value indicates whether the development of the construct has achieved its goal (Bond & Fox, 2007). In another aspect, ZSTD provides information to the researcher whether the data obtained really conforms to the instrument model. Any item that fails to meet one of the criteria in Table 3 needs to be modified or dropped so that the item fit value can be increased (Sumintono & Widhiarso, 2015).

Table 3
Fit Indices for Item Fit

Statistics	Fit Indices
Outfit mean square values (MNSQ)	0.50 – 1.50
Outfit z-standardised values (ZSTD)	-2.00 – 2.00
Point Measure Correlation (PTMEA-CORR)	0.40 – 0.85

Source: Boone et al. (2014)

Rasch analysis can also be used to identify item polarity through PTMEA-CORR values. A positive PTMEA-CORR value indicates that the item can accurately measure what it needs to measure and vice versa if its value is negative. The researchers also assess the instruments' unidimensionality to guarantee that the instrument can successfully measure the construct of entrepreneurial science thinking (Sumintono & Widhiarso, 2015). Component Analysis provides dimensional criteria based on the 'raw variance explained by measures' (Sumintono & Widhiarso, 2015). The accepted value of 'raw variance explained by measures' should exceed 20%, is considered good if it is more than 40% and considered excellent if more than 60%. Meanwhile, the value of 'unexplained variance in first contrast' should not exceed 15%.

In terms of reliability, the researcher referred to Sumintono and Widhiarso (2015) for Cronbach's alpha value (KR-20), item-person reliability and separation indices (Table 4). The separation index of persons was used to classify the level of learners. A good separation index should be >2, where the higher the separation index, the better the level of classification of persons. Item separation index was also used to validate the item hierarchy. The low item separation index value, <3 shows that the sample of learners was not large enough to confirm the hierarchy of item difficulty in the instrument. Linacre (2002) insisted that a high separation value indicates that the instrument has good quality since it can identify the group of items and respondents.

Table 4
Reliability Measured via the Rasch Analysis

Statistics	Fit Indices	Interpretation
Cronbach's alpha (KR-20)	< .5	Low
	< .6	Moderate
	.6 – .7	Good
	.7 – .8	High
	.9 – 1.0	Very High
Item and Person Reliability Index	<.67	Low
	.67 – .80	Sufficient
	.81 – .90	Good
	.91 – .94	Very Good
	>.94	Excellent
Item Separation Index	>3	Good
Person Separation Index	>2	Good

Source: Sumintono & Widhiarso (2015) and Linacre (2002)

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Research Results

Content Validity

Content validity indicates the extent to which an item adequately represents the content of a trait that a researcher wants to measure (Creswell & Creswell, 2017). Kline (2005) stated that an experts' review is necessary to ensure the accuracy of the construct as well as the clarity of its contents. Mullen (2003) remarked that a group of experts are those who are trained in a specific field. Therefore, the researchers showed the ESTT to five experts who had vast knowledge in the fields of entrepreneurial science thinking, Science Education and STEM Education. The researchers used an item evaluation form adapted from the Malaysian Examinations Board (2013). The panel of experts evaluated ESTT items from the aspects of conformity, accuracy, and clarity as well as suitability. Comments from the experts were recorded and taken into consideration for the ESTT instrument improvement process. Table 5 shows the list of experts involved in the content validation panel.

Table 5
Content Validation Panel for ESTT

Name	Institute	Designation	Expertise
Expert A	University	Professor (PhD)	Science Entrepreneurial Thinking
Expert B	Teachers Training Institute (TTI)	Academic Lecturer STEM Department (PhD)	Curriculum and Instructional (Science)
Expert C	Teachers Training Institute (TTI)	Academic Lecturer STEM Department	Science Education
Expert D	Primary School	Head of Science Panel (PhD)	STEM Education and Scientific Creativity
Expert E	Primary School	Science Subject Coach	Science Education (Primary School)

Based on Table 6, all items in ESTT were accepted and the value obtained from the Scale Content Validity Index (S-CVI) was .92. This S-CVI value meets the requirement of ≥ .80 as set by Polit et al. (2017) for new instruments. The S-CVI index of .92 indicated that the expert panel regarded the content validity of the ESTT instrument as very high and acceptable.

Table 6
Content Validity Index (CVI) Results of the ESTT Instrument

Item	Expert A	Expert B	Expert C	Expert D	Expert E	Experts in Agreement	I-CVI	Results
1a	-	/	/	/	/	4	.80	Accepted
1b	-	/	/	/	/	4	.80	Accepted
2a	-	/	/	/	/	4	.80	Accepted
2b	-	/	/	/	/	4	.80	Accepted
3a	/	/	/	/	/	5	1.00	Accepted
3b	/	/	/	/	/	5	1.00	Accepted
4a	/	/	/	/	/	5	1.00	Accepted
4b	/	/	/	/	/	5	1.00	Accepted
5a	/	/	/	/	/	5	1.00	Accepted
5b	/	/	/	/	/	5	1.00	Accepted
Scale Content Validation Index/ Average (S-CVI/Ave)							.92	

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Construct Validity

Person Fit

Table 7 displays the persons (which are the fifth graders in this case), whose responses were most ill-fitting with the Rasch analysis; or in other words, their responses contrasted from the estimation given by the Rasch model. The fifth graders were ranked according to the highest ZSTD Outfit value. Among the fifth graders, there were seven respondents (063, 100, 127, 166, 004, 002 and 022) who scored an Outfit ZSTD value higher than 2.0. The remaining fifth graders scored an Outfit ZSTD value within the acceptable range (from -2.0 to +2.0). Fifth graders whose responses gave negative PTMEA-CORR readings showed that they made decisions out of the usual.

Table 7
Misfit Order of the Persons in ESTT Instrument

Person	MNSQ Outfit (.50-1.50)	ZSTD Outfit (-2.0-2.0)	PTMEA-CORR (.40 - .85)
063	9.90	3.9	- .38
100	9.90	4.5	- .44
127	9.90	3.1	- .25
166	7.33	2.5	- .12
004	5.72	2.8	- .02
002	2.97	2.2	.08
022	2.97	2.2	.08

In addition, there were 10 fifth graders who attained extreme marks (maximum marks) namely, students 020, 044, 068, 076, 084, 088, 093, 096, 109, and 161 (Figure 2). A total of 17 fifth graders were excluded and 149 respondents out of the 166 respondents were involved with the next analysis. This denotes that in the pilot study, the items were fit for almost all the students (89.76%) and the analysis conducted on those fifth graders showed quality findings for the assessment using the Rasch analysis.

Figure 2
Person with Extreme Scores

```
INPUT: 166 Person  10 Item  REPORTED: 166 Person  10 Item  3 CATS  WINSTEPS 3.73
-------------------------------------------------------------------------------
Person: REAL SEP.: 2.44  REL.: .86 ... Item: REAL SEP.: 6.86  REL.: .98

         Person STATISTICS:  MEASURE ORDER

-------------------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT    |  OUTFIT   |PT-MEASURE |EXACT MATCH|         |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ   ZSTD|CORR.   EXP.| OBS%  EXP%| Person|
|------------------------------------+----------+-----------+-----------+-----------+--------|
|    20     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 020    |
|    44     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 044    |
|    68     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 068    |
|    76     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 076    |
|    84     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 084    |
|    88     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 088    |
|    93     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 093    |
|    96     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 096    |
|   109     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 119    |
|   161     30     10     7.51    1.89|       MAXIMUM MEASURE| .00    .00|100.0 100.0| 161    |
|     1     29     10     6.13    1.12|1.18    .5| .79     .3| .22    .29| 90.0  90.0| 001    |
|     3     29     10     6.13    1.12|1.15    .4| .72     .3| .24    .29| 90.0  90.0| 003    |
|    12     29     10     6.13    1.12|1.18    .5| .79     .3| .22    .29| 90.0  90.0| 012    |
|    16     29     10     6.13    1.12|1.08    .4| .59     .1| .28    .29| 90.0  90.0| 016    |
|    19     29     10     6.13    1.12|1.18    .5| .79     .3| .22    .29| 90.0  90.0| 019    |
```


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Item Fit

Linacre (2007) emphasised that the value of MNSQ Outfit provides a strong value in determining the suitability of items for the measurement of a construct. Boone et al. (2014) ascertained that the suitable product value range is between .5 to 1.5 based on MNSQ Outfit, between -2 to +2 range for ZSTD Outfit and between .4 to .85 range for PTMEA-CORR. Any items that are outside the range of Outfit MNSQ, Outfit ZSTD, and PTMEA-CORR are considered inappropriate (Boone et al., 2014). However, if the item meets one of the criteria, the item must be retained (Sumintono & Widhiarso, 2015).

Based on Table 8, there are four items (1, 4, 7 and 9) that are outside the range of items. Boone et al. (2014) and Aziz et al. (2014) stated that items situated outside the range and which do not meet all three criteria are considered unsuitable. However, if the item meets one of the criteria, the item must be retained (Sumintono & Widhiarso, 2015). Table 8 shows that all the items meet at least one criterion. Thus, no items were changed and removed from the instrument.

Table 8
Misfit Order of the Items in ESTT

Item	Outfit MNSQ (.50-1.50)	Outfit ZSTD (-2.0 - 2.0)	PTMEA-CORR (.40 - .85)	Result
I7	1.57	3.2	.54	retained
I2	1.35	.7	.78	retained
I5	1.33	.9	.79	retained
I3	1.26	1.2	.77	retained
I8	.55	- .4	.76	retained
I9	.36	- .9	.69	retained
I6	.92	- .5	.64	retained
I10	.87	-1.0	.85	retained
I4	.67	-2.7	.84	retained
I1	.52	-3.5	.90	retained

Item Polarity

Based on Table 8, the minimum value of PTMEA-CORR is .54 while the maximum value is .90. These positive values indicated that all the items functioned in a parallel direction while negative values showed which items needed to be repaired or dropped. The item polarity analysis using PTMEA-CORR values elucidates that the items in ESTT move in the same direction according to the measured construct (Linacre, 2002).

Unidimensionality

Unidimensionality is important to determine that the instrument being developed can measure in one direction and ensure precise results from the study. Unidimensionality is frequently detected by using the Principal Component Analysis of Rasch Residual (PCAR). Based on Figure 3, the observed value of the Raw Variance Explained by Measures is 66.8%. Values exceeding the 60% index are at an excellent level and it is proven that ESTT instruments have a strong unidimensionality. This shows that ESTT can measure constructs in science entrepreneurial thinking. The value of 6.6% was detected from the Unexplained Variance in the 1st Contrast, which was less than 15%.

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Figure 3
Principal Component Analysis of Rasch Residual (PCAR)

```
INPUT: 149 Person  10 Item  REPORTED: 149 Person  10 Item  3 CATS  WINSTEPS 3.73
--------------------------------------------------------------------------------

     Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                             -- Empirical --    Modeled
Total raw variance in observations     =     30.1 100.0%         100.0%
  Raw variance explained by measures   =     20.1  66.8%          65.7%
    Raw variance explained by persons  =     13.7  45.6%          44.9%
    Raw Variance explained by items    =      6.4  21.2%          20.8%
  Raw unexplained variance (total)     =     10.0  33.2% 100.0%   34.3%
    Unexplned variance in 1st contrast =      2.0   6.6%  19.7%
    Unexplned variance in 2nd contrast =      1.5   5.0%  15.0%
    Unexplned variance in 3rd contrast =      1.2   4.0%  12.1%
    Unexplned variance in 4th contrast =      1.2   3.8%  11.6%
    Unexplned variance in 5th contrast =      1.1   3.7%  11.0%
```

Reliability and Separation Indices

In relevance to the reliability of ESTT, the person measure reliability indicates how well the fifth graders can be distinguished based on their responses. The item measure reliability specifies how well the items (statements) can be discriminated from one another based on their authenticity approved by the respondents. The reliability findings overview is summarized in Table 9.

Table 9 presents the ESTT's reliability values based on Cronbach's coefficient alpha (KR-20). The value achieved was .91. This infers that the reliability of the ESTT is within a very high range (Sumintono & Widhiarso, 2015). The item reliability value of .98 is within a very high range (Bond & Fox, 2007; Linacre, 2007). The item separation index was 7.97, which is more than 3.0. This value proved that ESTT has a good spread of items (Linacre, 2007) that it could distinguish the respondents according to the hierarchy of item difficulty in ESTT.

The person reliability of .89 was also within a good range, whereas the person separation value in ESTT was 2.83. Bond and Fox (2007) stated that the respondents' reliability value, which is higher than .80, indicates that the respondents gave good and consistent feedback. The item separation value of more than 2.00 indicates there is enough spread of items (Linacre, 2002). The value of 2.83 points out that the fifth graders could be divided into three groups according to their responses to the items in ESTT.

Table 9
Summary of the Reliability Findings

	Rasch Measurement	ESTT	Interpretation
Cronbach's alpha (KR-20)	.9 – 1.0	.91	Very high
Item Reliability	>.94	.98	Excellent
Item Separation Index	> 3.0	7.97	Good
Person Reliability	.81 – .90	.89	Good
Person Separation Index	> 2.0	2.83	Good

Discussion

In this research, ESTT was developed to assess the level of entrepreneurial science thinking among fifth graders. In addition to its importance in determining the extent of entrepreneurial science thinking, this ESTT also offers added value in the analysis of entrepreneurial science thinking in STEM Education.

Overall, the Rasch Measurement Model was used to assess the validity and reliability of ESTT. Five constructs,

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namely Observation, New Ideas, Innovation, Creativity and Value, were established as the focus of the ESTT instrument. All ten open-ended items went through the content validation phase by five experts. The items for the Observation Construct were adjusted from observation about energy and the transformation of energy to the observation of building materials and design. This is to guarantee that the scientific principles of materials are tested during the Observation Construct. In addition, the researcher also changed the question's keyword from 'what' to 'explain' for the construction of the New Ideas construct. It is to ensure that fifth graders are subjected to the engagement of high-level thinking.

The construct validity analysis was conducted for item and person fit, item polarity as well as unidimensionality. The results of Rasch's analysis show that ESTT has good psychometric quality. A positive PTMEA-CORR analysis indicates that all items move in the same direction in measuring the constructs to be measured (Bond & Fox, 2015; Linacre, 2012). Meanwhile, the obtained Raw Variance Explained by Measures value of the ESTT instrument proved that the ESTT instrument truly measures the construct of entrepreneurial science thinking. In other words, there was no sixth construct in ESTT (Aziz et al., 2015; Fisher, 2007).

The ESTT instrument was also tested for its reliability and separation index. According to Cohen and Swedlik (2018), a good set of test items can be distinguished by respondents. The ESTT instrument was found to have very high Cronbach's alpha value, excellent item reliability value and good person reliability. These findings show that the reliability of ESTT instrument is high in assessing the entrepreneurial science thinking of fifth graders in STEM education. The obtained good item separation value shows that ESTT instrument can be categorized into eight strata of items levels while the obtained person separation value proves that fifth graders can be divided into three strata according to ability level.

Most instruments developed by previous researchers (Li et al., 2016; Bolton & Lane, 2012; Schelfhout et al., 2016) concentrate on high school and undergraduate students' level of entrepreneurial thinking in the field of engineering and entrepreneurship education. This limitation was addressed with the development of ESTT.

Research findings confirm that ESTT is explicitly in line with Kolb (1984)'s experiential learning theory and offer a new instrument for primary school children in STEM education. ESTT helps educators obtain preliminary data on the extent of children's entrepreneurial science thinking in primary schools. The data can then be used to develop appropriate education programs to enhance entrepreneurial science thinking. As reported by Gray (2016), the level of entrepreneurial thinking is essential to anticipate learners' future potential in STEM.

This study has also shown that the level of entrepreneurial thinking among primary school children can be assessed by referring to the appropriate entrepreneurial Thinking Model. Moreover, ESTT utilises an open-ended questions approach, which allows children to offer their views more freely based on their current experience and knowledge (Liñán & Chen, 2009). In addition to that, most previous entrepreneurial thinking instruments used the exploratory factor analysis method, while ESTT uses Rasch analysis, which leads to the accuracy of the instrument developed.

Conclusions and Implications

This research has several implications that impact practicality and methodology. In terms of practicality, the ESTT is a new instrument developed by researchers based on Kolb's Experiential Learning Theory and the Entrepreneurial Science Thinking Model and was adapted to suit the context of STEM Education. Thus, the Entrepreneurial Science Thinking Test (ESTT) instrument is fit to fill the gap in STEM education research and overcome the issue of the lack of instruments that measure entrepreneurial science thinking among primary school children. The development of this instrument is a significant endeavour in warranting the continuity of the application of entrepreneurial science thinking in STEM Education which will ultimately contribute to a generation of inventors and creators.

In terms of methodology, the Rasch Model of Measurement is more specific and detailed in determining the validity and reliability of the ESTT instrument. The Rasch measurement model's analysis of instrument validity in terms of item-person fit, item polarity and unidimensionality showed that ESTT instrument has a high validity in measuring entrepreneurial science thinking in STEM education. The high reliability analysis of ESTT instrument with good item-person separation value proved that ESTT instrument is reliable for measuring entrepreneurial science thinking in STEM education for fifth graders. This study also demonstrated that instruments that have gone through a phase of validity and reliability will help the researcher measure the variables studied and make accurate decisions based on the analysis of the findings. In fact, these findings provide a basis for other researchers so that the ESTT instrument can be distributed to learners in other areas. Ultimately, the validity and reliability

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analysis using the Rasch Measurement Model successfully proved that the ESTT instrument is very suitable for real field study in assessing entrepreneurial science thinking in STEM education among children in primary schools.

Even though the findings suggest that ESTT is a reliable and valid instrument for STEM education, its limitations should be acknowledged. ESTT was tested in five primary urban schools using a sample of 166 fifth graders, it may not be representative of the general population of primary school students. Future research needs to involve a bigger sample size, including rural schools. ESTT can be infused into any STEM curriculum integrated model to promote better critical and inventive thinking skills in STEM. It is suggested to extend the usage of ESTT instrument to other regions of the country, as well as to a variety of learners for greater generalisability.

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Declaration of Interest

Authors declare no competing interest.

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UPPER-SECONDARY SCHOOL SCIENCE TEACHERS' PERCEPTIONS OF THE INTEGRATING MECHANISMS AND IMPORTANCE OF STEM EDUCATION

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Abstract. *This study aimed to recognize upper-secondary school science teachers' perceptions of the meaning, importance, and integrating mechanisms of science, technology, engineering, math (STEM) education, taking in to account the differences between the science teachers' perceptions according to their specialties, years of experience, and degrees. A closed-ended questionnaire was distributed among 700 science teachers (biology, physics, and chemistry) in Riyadh, and 255 teachers responded. The results showed a strong alignment in the upper-secondary school science teachers' perceptions of the meaning and the importance of STEM education, although there was less of a consensus regarding the integrating mechanisms. There were statistically significant differences in the physics teachers' perceptions of STEM meaning, although there were otherwise no significant differences by specialty in the science teachers' perceptions of the importance of STEM education and its integration mechanisms. Furthermore, the teachers showed no statistically significant differences in STEM's meaning, importance, or integrating mechanisms according to their years of experience. Based on the results, recommendations included intensifying professional development programs on utilizing technology, engineering, and mathematics in learning science concepts and application.*

Keywords: *integration mechanisms, science teachers, STEM education, teachers' perceptions, upper secondary school*

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Introduction

The science curriculum is considered one of the pillars of scientific and technological progress; it contributes to developing learners' knowledge and applied skills as well as expanding on science trends. However, there is a gap between what is taught in schools and what students need in their lives and to succeed in the job market. One means of addressing this gap in learning is taking advantage of global visions and experiences in science education.

Because of the natural overlap between science, technology, engineering, and mathematics, science curricula have evolved to reflect the relationships among the fields. In the 1990s in the United States, the National Science Foundation created a consolidated science, technology, engineering and mathematics (STEM) education topic to expand the skilled and innovative workforce by enhancing students' ability to build and produce science knowledge across the four integrated fields (Misher, 2014).

A committee that consisted of the National Academy of Engineering and the National Research Council (NAE & NRC, 2014) defined science as studying and investigating the natural worlds, mathematics as studying relationships between quantities to build logical arguments, engineering as knowledge about design and product construction, and technology as knowledge, processes, and tools that relate to employing and producing technology. The mechanisms of integrating these fields vary because of differing educational strategies and different special features across fields (NAE & NRC, 2014). For instance, some curricula might aim to teach science, technology, engineering, and mathematics integrally, while others might incorporate some aspects of the STEM fields to support teaching other fields (Bybee, 2013).

However, what best facilitates the integration of the STEM fields into teaching is focusing on major ideas, for example, connecting a problem or a concept to learners' realities (Mcgehee, 2015). The Next Generation Science Standards (NGSS) were developed to reflect this enhanced understanding of science and engineering practices so as to build on learners' knowledge through a variety of practices. Specifically, the new standards aimed to clarify

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how to accomplish the following: define problems and ask questions, develop and use models, plan and conduct investigations, analyze and interpret data, use mathematics and computational thinking, interpret findings and design solutions, and generally participate in science debate based on obtaining, analyzing, interpreting, and communicating evidence (NRC, 2012).

Several researchers have identified positive impacts of teaching in accordance with STEM education on forming positive attitudes toward STEM (Laforce et al., 2017; Lou et al., 2010; Misher, 2014), improving academic achievement (Al-Qathami, 2017; Al-Shehimiah, 2015; Najjar, 2015; Wahono et al., 2020), and developing 21st-century skills (Husin et al., 2016), thinking habits (Al-Daoud, 2017; Najjar, 2015), thinking skills (Al-Qathami, 2017), decision-making skills (Al-Daoud, 2017; Rizk, 2015), creative thinking (Al-Shehimiah, 2015), and motivation (Wahono et al., 2020). Given the importance of STEM education and its reliance on teachers' understanding and attitudes toward it (NAE & NRC, 2014), recognizing teachers' perceptions of STEM education could contribute to helping them organize their knowledge and understand their behaviors (Owens, 2014; Turner, 2013).

The global interest in STEM education is evident as it is included in 798 articles in 36 journals during the period of 2000 to 2018. However, the topics related to teacher and STEM teaching of K-12 comprised 12.9% (Li et al., 2020), and this may highlight the need for more research on teachers, particularly their perceptions, of what notions contribute to guiding teaching decisions (Shahzad et al., 2017). Some local and international studies that were conducted on science teachers' perceptions of STEM education have shown positive perceptions of the STEM concept (Al-Anzi and Al-Jabr, 2017; Ambosaidi et al., 2015; Smith et al., 2015), and its importance (Amir et al., 2015; Park, et al., 2016; Turner, 2013; Wang, 2012). These results were revealed after teachers had received training courses on STEM education for 8 hours, as the study of Amir et al. (2015), or 3 weeks, as the Turner's (2013) study, or a year and a half, as Wang's (2012) study. On the other hand, the studies of Al-Anzi and Al-Jabr (2017) and Ambosaidi et al. (2015) revealed the perceptions of Science educators about the concept of STEM education and its teaching requirements prior to the enrollment in professional development programs about STEM.

Several studies have revealed the relationship between teachers' perceptions of STEM education and some variables. The first variable is teaching practices, such as the studies of Owens (2014) and Wang (2012), which made it clear that teachers' perceptions appeared clearly in their teaching practices when they were observed in the classroom. The second variable is years of experience, such as the study of Al-Anzi and Al-Jabr (2017), Park et al. (2016), Ambosaidi et al. (2015), and Smith et al. (2015), whose results did not show statistically significant differences in teachers' perceptions of STEM that attributed to their years of experience. However, the study of Park et al. (2016) showed statistically significant differences in teachers with more than 15 years of experience. The third variable is gender. The study of Park et al. (2016), Ambosaidi et al. (2015), and Smith et al. (2015) showed statistically significant differences in teachers' perceptions of STEM for male teachers. The fourth variable is educational stages. The studies of Al-Anzi and Al-Jabr (2017) and Park et al. (2016) showed statistically significant differences in the teachers' perceptions of STEM which were found in favor of elementary school teachers.

Changing perceptions is difficult and may take a long time as it has gone through several stages: "awareness, development of interest, mental experimentation, actual experimentation, then adoption or rejection" (Al-Saleh, 2002, p. 10). Thus, this study aimed to know the perceptions of science teachers before applying STEM education in schools, or before joining professional development. It may give results that would contribute to guiding professional development programs. With a careful extrapolation of the previous studies, it becomes clear that there are no local studies that have dealt with the perceptions of science teachers at the secondary level about the concept, importance, and mechanisms of STEM education.

Research Problem

Scholars in Saudi Arabia have identified challenges to incorporating technology and engineering into science textbooks. Efforts have focused on the theoretical aspect of technology and its role in science research more than on engineering design or on connecting technology to science problems in society (Al-Ahmad & Al-Buqami, 2017; Al-Beez, 2017; Al-Hamidani, 2017; Al-Ahmadi, 2016); moreover, the natural sciences are rarely integrated (Al-Beez, 2017; Al-Hamidani, 2017). These shortcomings could negatively affect learners' understanding of science concepts or their abilities to face scientific problems and solve them. Learners in the Trends of the International Mathematics and Science Studies (TIMSS, 2019) performed below the average (Al-Shamrani et al., 2016).

One of the supporting steps of the transformation to a more productive society that can confront problems related to science is keeping up with new trends in science education such as STEM education. The interest in this

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trend was reflected in newly established science centers and STEM education conferences, but despite the interest in applying STEM education, there are some challenges. In particular, STEM education tends not to be included in teacher preparation courses, and many districts in Saudi Arabia have large numbers of schools and teachers (Al-Dossary, 2015). Al-Daoud (2017) recommended identifying science teachers' perceptions about this trend, and Al-Anzi and Al-Jabr (2017) conducted a study to do so; specifically, they studied science teachers' perceptions of STEM education teaching requirements. However, no researchers in Saudi Arabia have examined the meanings and importance of STEM for science teachers or their perceptions of integrating mechanisms. This study aimed to fill that research gap with a focus on whether science teachers' perceptions varied according to their years of experience, field of specialization, or academic degree.

Research Questions

1. What are upper-secondary school science teachers' perceptions of STEM education in terms of its concept, integrating mechanisms, and importance?
2. Are there any statistically significant differences ($\alpha \leq .05$) among upper-secondary school science teachers' perceptions of STEM education by specialization?
3. Are there any statistically significant differences ($\alpha \leq .05$) among upper-secondary school science teachers' perceptions of STEM education by years of experience?
4. Are there any statistically significant differences ($\alpha \leq .05$) among upper-secondary school science teachers' perceptions of STEM education by academic degree?

Research Significance

1. This study responds to recent trends in science education.
2. The value and importance of science teachers' voices in improving science education by identifying science teachers' perceptions of STEM education as previous studies assured (Owens, 2014; Shahzad et al., 2017; Wang, 2012).
3. The results could help in designing professional development programs that meet the needs of science teachers.

Research Terms

Perception is a mental process that enables individuals to construct ideas, opinions, or concepts based on their personal experiences, feelings, and needs, and teachers' perceptions have a recognized effect on their classroom actions (Choy & Cheah, 2009). Practically, perception in this study refers to science teachers' opinions about the importance of STEM education and the mechanisms of integrating different STEM concepts as well as the influence of their perceptions on their teaching performance.

STEM education refers to curricula that attempt to integrate science, technology, engineering, and mathematics into one category based on the connections in the natural world (Stohlmann et al., 2012). For this study, STEM education refers to instruction methods that enhance learners' holistic understanding and utilization of STEM concepts and practices.

Integrating mechanisms refer to methods and forms of integrating science, technology, engineering, and mathematics (Bybee, 2013). Mechanisms of integrating the different topics can vary according to the specificity of academic subjects or the diversity of educational strategies (NAE & NRC, 2014) and depend on the learning context, how science content is organized, and who is teaching.

Research Methodology

General Background

For this descriptive study, the researchers used a questionnaire, a tool with which "all members of the research community, or a large sample of them, are questioned to describe the studied phenomenon, in terms of its nature, and the degree of its existence, without going beyond that to study the relationship or deduce the causes" (Al-

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Assaf, 2016, p. 211). A survey was the most appropriate approach for collecting, describing, and interpreting the data on science teachers' perceptions of STEM education. The study was applied during the academic year 2018. And it was limited to girls' public and private upper-secondary schools in the city of Riyadh due to the separation between girls and boys in Saudi schools.

Population and Participants

According to the statistics of the Riyadh Education Department (2017), the population included 1,754 upper-secondary school science teachers from private and public schools in Riyadh, Saudi Arabia. A sample of 700 upper-secondary school science teachers was chosen from the population through stratified sampling based on science specialization. To ensure that the study takes into account the ethics of scientific research, a brief description of the study objectives, procedures, and tools has been sent to the Scientific Research Ethics Committee at King Saud University to get their permission. The research objectives have been clarified for the sample in the tool, and it is assured that they observe the confidentiality of their data. It was also ensured that the letter sent by the Ministry of Education to science teachers did not include any mandatory formula to answer the questionnaire. The information and the questionnaire were sent by the Information Technology Department at the Ministry of Education to the sample via text messages. However, although the sample comprised 40% of the population, only 255 teachers responded, accounting for approximately 15% of the population; the sample consisted of 92 biology teachers, 78 physics teachers, and 85 chemistry teachers. In terms of their years of experience, 7% of the teachers had been teaching for less than five years, 27% had between five and 10 years of experience, and 66% had taught for more than 10 years. By academic degree, 86% of the teachers in this study held a bachelor's degree, 14% held a master's degree, and only one held a doctorate. All members of the sample were female.

Instrument and Procedures

The questionnaire consisted of two parts. The first part asked the respondents about their years of experience, specialties (biology, physics, and chemistry), and academic degree; the second part had three sections: STEM meaning, importance, and mechanisms for integrating. The number of items in each section was 13 in STEM meaning, seven items in mechanism for integrating, and eight items in importance. These items reflected the scientific visions of the NEA and NRC (2014) and Bybee's (2013) integrating mechanisms. The participants rated each questionnaire item on 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree, and 5 = strongly agree). The researchers then divided the responses into one of four categories: high, medium, low, and very low.

Reliability and Validity

The researchers validated the questionnaire by presenting it to a group of experts in curriculum and instruction and calculated the internal consistency reliability using Pearson's correlation coefficient. The results ranged between .985 and .609, which indicated that each questionnaire item had a medium to high internal correlation and, thus, confirmed the reliability for implementation (Abu Hashem, 2012). Moreover, the researchers administered the questionnaire to a pilot sample that comprised 30 upper-secondary school science teachers and calculated a Cronbach's alpha of .983, which reflected a high reliability (Allam, 2007).

Data Analysis

Various statistical methods were used to analyze the data. Descriptive statistics included frequencies (mean and standard deviations) of each item of the questionnaire were calculated to find science teachers' perceptions of STEM education. One-way analysis of variance (ANOVA) was conducted to find the differences in science teachers' perceptions of STEM education according to their years of experience and specialization (biology, physics, chemistry). Scheffe's test for post-hoc comparisons was used to distinguish the teachers' differing perceptions according to their experience and specialties. A t-test was used to detect differences in science teachers' perceptions of STEM education according to their academic degrees.

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Research Results

The findings for the first study question, on upper-secondary school science teachers' perceptions of STEM education, revealed strong agreement in the teachers' perceptions of the meaning of STEM (M = 4.26). Specifically, the two most commonly selected STEM meanings were "connecting learning scientific concepts with issues and problems of the natural world" and "preparing a stimulating learning environment to show students' correct and incorrect concepts and discussing them." In contrast, the two lowest-ranked STEM meanings are "employing simulation software to build predictions about the engineering design performance related to scientific concepts" and "developing students' engineering practices, such as creating or drawing engineering designs, then evaluating and developing them to understand or solve scientific problems" (see Table 1).

Table 1
Means and Standard Deviations of Science Teachers' Perceptions of STEM Meaning

Item	*M*	*SD*	Ranking
STEM education meaning			
3. Connecting learning scientific concepts with issues and problems of the natural world related to environment, energy, health, climate change.	4.41	0.651	1
11. Preparing a stimulating learning environment to show students correct and incorrect concepts and discussing them.	4.40	0.762	2
12. Preparing a motivating learning environment to generate students' questions.	4.40	0.766	3
13. Prepare a stimulating learning environment for students to evaluate each other's ideas based on evidence and arguments.	4.35	0.784	4
9. Engaging students in realistic experiences in which they employ science, technology, engineering, and math concepts and practices.	4.34	0.674	5
10. Directing the students to determine scientific problems, design and propose solutions, and perform implementation, interpretation and analysis by themselves.	4.32	0.725	6
5. Students' employing technology to build or apply their scientific knowledge.	4.31	0.666	7
6. Employing technologies to support dialog and communication between students, researchers, and scholars.	4.31	0.739	8
2. Students learn science concepts in the light of science phenomena or problems in ways that integrates the related scientific disciplines.	4.21	0.794	9
7. Students use mathematical models to build scientific explanations or engineering designs.	4.16	0.711	10
1. Lessons are structured in the form of key concepts that connect science, technology, engineering, and mathematics.	4.16	0.713	11
8. Employing simulation software to build predictions about engineering design performance related to science concepts.	4.11	0.789	12
4. Developing students' engineering practices, such as creating or drawing designs, evaluating them, and developing them to understand or solve science problems.	4.07	0.783	13
1-13	4.26	0.512	-

The mean rating for science teachers' perceptions of how to integrate STEM is 3.84. The mechanism that the most participants agreed on was holding activities that support learning mathematics, technology, and engineering and help students learn and apply science concepts; the mean rating for this mechanism is 4.24. The integrating mechanism that the science teachers agreed on the least was attempting to teach all four STEM concepts in one course in collaboration among the different teachers. The mean rating for this integration mechanism is 3.33 (see Table 2).

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Table 2
Means and Standard Deviations of Science Teachers' Perception of STEM Integrating Mechanism

Item	*M*	*SD*	Ranking
STEM integrating mechanism			
1. Activities that support learning mathematics, technology, and engineering and help students learn and apply scientific concepts.	4.24	0.693	1
6. Project-based learning that helps students employ concepts and practices in science, technology, engineering, and mathematics.	4.13	0.805	2
7. Create a unit related to contemporary issues or challenges that require students to employ previously studied STEM concepts and practices.	3.98	0.827	3
5. Combining two or three STEM fields to construct or apply integrated scientific knowledge.	3.87	0.839	4
3. Teaching science, technology, engineering, and mathematics in (separate) coordination between teachers' specializations to support students' knowledge and skills to solve specific science problems.	3.73	1.057	5
2. Utilizing technology or engineering to build concepts of science and mathematics.	3.63	1.132	6
4. Teaching science, technology, engineering, and mathematics in one course in cooperation between the teachers of these fields to support students' knowledge and practices to solve specific scientific problems.	3.33	1.233	7
1-7	3.84	0.608	-

The results also showed a strong agreement in the science teachers' perceptions of the importance of STEM, with a mean rating of 4.15. The teachers agreed that the most important aspect of STEM is "developing students' skills in solving science problems using creative methods." The two importance measures that the science teachers rated as the least important are "improving students' academic achievement" and "developing students' desire to engage in understanding and solving natural world problems related to science, technology, engineering, and mathematics" (Table 3).

Table 3
Means and Standard Deviations of Science Teachers' Perceptions of STEM Importance

Item	*M*	*SD*	Ranking
STEM importance			
6. Developing students' skills in solving science problems using creative methods	4.38	0. 700	1
1. Developing students' knowledge in science, technology, engineering, and mathematics.	4.37	0.625	2
4. Developing students' skills in critical thinking.	4.37	0.632	3
5. Developing students' skills in decision-making.	4.35	0.681	4
8. Enhancing students' awareness of the roles of science, technology, engineering, and mathematics together in addressing major challenges in society.	4.33	0.676	5
2. Developing students' science, technology, engineering, and math practices.	4.30	0.698	6
7. Improving students' academic achievement.	4.30	0.714	7
3. Developing students' desire to engage in understanding and solving natural world problems related to science, technology, engineering, and mathematics.	4.29	0.695	8
1-8	4.34	0.560	-
STEM meaning, integrating mechanisms, and importance	4.15	0.488	-

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For study question 2, regarding statistically significant differences in the upper-secondary school science teachers' perceptions of STEM education by science, Table 4 presents the univariate test findings. In particular, *F* for STEM meaning is 3.828, and *p* = .023. However, the univariate tests indicate that the teachers' perceptions of STEM's meaning and importance and of mechanisms for integrating the STEM concepts differed according to their specialization, with *F* = 3.430 and *p* = .034. Scheffe's test for post-hoc comparisons is used to distinguish the teachers' differing perceptions according to their specialties. Univariate testing reveals significant differences; the Scheffe's test results are presented in Table 5, which reflects particular differences between the physics and biology teachers' varying STEM perceptions.

Table 4
Univariate Test Results for Science Teachers' Perceptions of STEM Education by Specialization

First part	Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Meaning	Between groups	1.967	2	0.983	3.828	.023
	Within groups	64.73	252	0.257		
	Total	66.70	254			
Integrating mechanisms	Between groups	1.619	2	0.809	2.214	.111
	Within groups	92.12	252	0.366		
	Total	93.74	254			
Importance	Between groups	1.307	2	0.653	2.102	.124
	Within groups	78.33	252	0.311		
	Total	79.64	254			
Total	Between groups	1.605	2	0.803	3.430	.034
	Within groups	58.97	252	0.234		
	Total	60.58	254			

Table 5
Scheffe's Post-Hoc Comparisons

Variables	Specialization		Mean Difference	*p*
The concept	Physics	Chemistry	0.02683	.938
		Biology	0.20050	.039*
Science teachers' perceptions of STEM meaning, integrating mechanisms, and importance	Physics	Chemistry	0.03980	.857
		Biology	0.18803	.043*

Study question 3 asked whether there were statistically significant differences in upper-secondary school science teachers' perceptions of STEM education by years of experience. The findings in Table 6 show an *F* of .233, which was not statistically significant (*p* = .792), indicating that the teachers' perceptions of the meaning and importance of STEM as well as the mechanisms for integrating did not differ according to their years of experience.

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Table 6
Univariate Test Results for Science Teachers' Perceptions of STEM Education by Years of Experience

First part	Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Meaning	Between groups	0.146	2	0.073	.276	.759
	Within groups	66.556	252	0.264		
	Total	66.702	254			
Integrating mechanisms	Between groups	0.106	2	0.053	.142	.867
	Within groups	93.636	252	0.372		
	Total	93.742	254			
Importance	Between groups	0.122	2	0.061	.193	.824
	Within groups	79.52	252	0.316		
	Total	79.64	254			
Total	Between groups	0.112	2	0.056	.233	.792
	Within groups	60.46	252	0.240		
	Total	60.58	254			

Study question 4, the last question, was regarding statistically significant differences among upper-secondary school science teachers' perceptions of STEM education by academic degree. Table 7 indicates that *t* was 1.372, which was not statistically significant ($p = .171$). Thus, science teachers' STEM perceptions did not differ by their academic degrees.

Table 7
T-test Results for Science Teachers' Perceptions of STEM Education by Academic Degree

First part	Years of experience	*M*	*SD*	*t* test		
				t	*df*	*p*
The concept	Bachelor	4.26	0.510	1.722	253	.086
	Postgraduate	4.41	0.508			
Integrating mechanisms	Bachelor	3.83	0.609	0.620	253	.536
	Postgraduate	3.90	0.601			
The importance	Bachelor	4.31	0.562	1.344	253	.180
	Postgraduate	4.45	0.537			
Total	Bachelor	4.13	0.490	1.372	253	.171
	Postgraduate	4.25	0.471			

Discussion

Engineering is considered a foundation of STEM education. In this study, science teachers strongly agreed on the role of engineering in constructing and applying science concepts but ranked it last in importance in terms of the meaning of STEM. This could be attributed to the fact that science curricula are based on the

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National Scientific Education Standards, which place less emphasis on engineering practices than the NGSS. The teachers herein agreed on the role of mathematics in learning and applying science concepts. This result is consistent with findings by Al-Anzi and Al-Jabr (2017) and Ambosaidi et al. (2015) in that science teachers perceive considerable integration between science and mathematics.

In addition, the science teachers in this study agreed that "scientific activities that support learning mathematics, technology, and engineering and help students in learning and applying scientific concepts" were the most important mechanism for integrating the concepts of STEM in education. It was attributed to the aforementioned similarity between this mechanism and the structure of activities in science curricula. Some studies have indicated moderate levels in terms of the incorporation of mathematics into teaching from science books (Al-Hamidani, 2017; Al-Beez, 2017) but a minimal inclusion of technology and engineering (Al-Ahmad and Al-Buqami, 2017; Al-Beez, 2017; Al-Hamidani, 2017; Al-Ahmadi, 2016). The result herein agrees with the aforementioned findings and with those of Wang (2012), who found that science teachers recognized technology and math as tools that can help learners better understand science matters.

Furthermore, it was attributed to the high agreement among the science teachers in this study that "project-based learning helps students in employing concepts and practices in science, technology, engineering, and mathematics" to the existence of professional development programs for science teachers for project-based learning; it is, thus, not a new concept. This finding is consistent with those from Sandall (2016), Owens (2014), and Turner (2013) in that project-based learning has a fundamental role in integrating science, technology, engineering, and mathematics.

It was also considered that science teachers' moderate agreement on the importance of creating "a unit related to contemporary issues or challenges, which requires students to employ previous studied concepts and practices in science, technology, engineering and mathematics" was related to how science curricula often end with an investigative activity that aims to employ two or more STEM concepts and practices. Consistent with the findings herein, Al-Hamidani (2017) found statistically significant differences in incorporating STEM activities into physics teaching, in particular, for lab activities because these were designed in the form of projects. Additionally, it might be easier for teachers to guide students in applying previously taught concepts than to attempt to build new knowledge through course projects, a method Slough and Milam (2013) identified as common in school projects.

Moreover, the finding of science teachers' perceptions about the importance of STEM, for which there was a high agreement among them, is in agreement with previous studies. Park et al. (2016) found that teachers believed STEM teaching enhanced students' learning, creative thinking, and personality building, and the teachers in Turner's (2013) investigation believed that STEM teaching developed 21st-century skills. Wang (2012) also indicated that science teachers believed that STEM teaching gave learners the opportunity to apply their knowledge in life situations.

In addition, it was attributed to the fundamental differences between physics and biology teachers' perceptions of the meaning and importance of STEM and of integrating mechanisms to the fact that the nature of physics ties it more closely to concepts of geometry, algebra, and arithmetic than to biology. Abdel-Hamid et al. (2015) indicated that 46 engineering skills related to the following content should be incorporated into physics textbooks: vectors and analysis of forces and field, followed by algebraic skills (24 skills), arithmetic (11 skills), and statistical (5 skills).

In contrast, the absence of significant differences between science teachers' perceptions of STEM education by their years of experience or academic degrees can be attributed to the fact that the concept of STEM is based on philosophical and logical foundations that stem from the unity of scientific knowledge, which cannot be partially constructed or applied. Furthermore, "STEM" is a modern term, but its roots belong to the theory of constructivism, which existing science curricula are based on, and this makes it acceptable to science teachers irrespective of their education or years of experience. This finding is in agreement with Ambosaidi et al. (2015) and Smith et al. (2015) in that science and agriculture teachers did not differ in their perceptions of the concept of STEM according to their years of experience. However, the results of this study contradict Park et al.'s (2016) finding that teachers who had 15 or more years of experience were more accepting of the concept of STEM and its importance than teachers who had fewer than 5 years of experience. This difference may be attributable to the types of schools that were studied; specifically, Park et al. (2016) studied schools with a STEM focus.

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Conclusions and Implications

An interest in STEM education, as it supports the building and application of scientific knowledge to solve the problems of society and develop its economy, was an impetus to reveal the perceptions of science teachers of STEM. This study aimed to recognize science teachers' acceptance of STEM requirements and to guide professional development programs. However, due to the low response of the upper-secondary school science teachers to the research tool that came at a rate of 37.5% of the sample, the generalization of this study results became limit. Moreover, the sample of this study were female which limits the ability to generalize the results.

The results revealed a high level of agreement regarding the concept and importance of STEM. However, there were some difficulties related to the teachers' preparation. Thus, this study recommends intensifying professional development programs in terms of employing engineering. This will lead to learning science that goes beyond a general engineering framework and concepts. The programs should relate to the science content teachers are already teaching.

This study showed that in a rather high standard deviation values in some science teachers' perceptions of the integration mechanisms. Thus, an analytical study can be recommended to reveal mechanisms of integration in studies that have researched the effectiveness of STEM education on learning outcomes.

For future studies, researchers should explore the relationship between science teachers' perceptions of the concept of STEM and their teaching practices. Further, analytical studies should be conducted to identify mechanisms for integrating STEM concepts into science teaching using dependent variables such as learners' interest in STEM fields and learning.

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Declaration of Interest

Authors declare no competing interest.

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COMPARISON OF AUGMENTED REALITY AND CONVENTIONAL TEACHING ON SPECIAL NEEDS STUDENTS' ATTITUDES TOWARDS SCIENCE AND THEIR LEARNING OUTCOMES

Turki Alqarni

Abstract. *This study examined the impact of the Augmented reality (AR) use on Jordanian 6th grade students' attitudes towards science and their learning outcomes. A quantitative quasi-experimental study is preceded with the Pre-test and Post-test control group design model, where 24 students who identified to have special needs participated in this study and were randomly divided into two groups. Two groups, control group 12 students were taught conventionally, and 12 students were designated as the experimental group, they used the AR technology for four weeks. The two scales used in this research were reliable and validated. The results show significant results for the AR technology in enhancing student learning outcomes. Additionally, results supported that AR technology has the potential to enhance students with learning disabilities positive attitudes. The result shows that AR technology helped students in promoting positive attitudes towards students and enhance students learning outcomes.*

Keywords: *augmented reality, attitudes towards science, learning disabilities, learning outcomes*

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Introduction

The study of Science is a process that involves several complexities relating to problem identification, problem investigation, hypotheses formulation, data collection method planning, hypotheses testing, data collection, obtaining results and making conclusions (Meerah, 1998; Saidin et al., 2015). Literature highlighted that there is a decrease in science achievement among students (Bicer & Lee, 2019). In other related studies, abstract and ambiguous course contents lead to misunderstanding and low achievement levels among students (Erbas & Demirer, 2019). In the modern educational system, 3.5% of the students were evidenced to display reading problems, which constitute one of the top common and current learning disabilities displayed among them (Karamanoli & Tsinakos, 2015). Additionally, among disabled students, creative interactive activities, visual presentations, project-based learning, and school experiments that are centered on engagement and activities of students are of significant benefit (Obradovic et al., 2015). In this regard, there is a need to stimulate learning disabilities through the use of visual and perceptive activities (Rega & Mennitto, 2017), with literature evidencing that school students are slowly losing their interest and motivation towards learning science subjects (e.g., Cimer, 2012; Potvin & Hasni, 2014). In the face of the tireless efforts made by the educational systems around the globe in supporting special needs students, challenges still abound when it comes to their learning, which are related to the teaching approach, services provided, teachers with lack of experience with the students and identification of students suffering from learning disabilities (Alnahdi et al., 2019; Binmahfooz, 2019). As students with learning disabilities move from one stage to the next, academic requirements and expectations also increase. This is particularly true because evidence shows that learning disabilities have divergent characteristics (Billingsley et al., 2018), while more has to be researched on instructional practices enhancing learning outcomes, achievement and level of engagement of students with learning disabilities (Billingsley et al., 2018).

Therefore, promoting positive attitudes towards science courses among students is a crucial goal among academicians (Musalamani et al., 2021;

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Toma et al., 2019). Among educators, there is an increasing trend to develop and implement evidence-based practice in the hopes of preparation individuals with and without learning disability to live normal, productive, and enriching lives, through refining methodologies refinement and creation (Kellems et al., 2020). Regardless of the countless approaches to teaching, which have been adopted to enhance learning among students with and without disabilities in science courses, authors on the topic indicate inconclusive findings as to the effectiveness of intervention (Kellems et al., 2020; Savelsbergh et al., 2016). The education innovation literature brings forward advance technology as an innovation that could enhance learning outcomes and successful achievements of students in both groups (with and without learning disabilities) (Kellems et al., 2019; Savelsbergh et al., 2016). Advancements in technology have extended the limitations of teaching and learning activities and the development of methods to deliver new courses (e.g., e-learning, virtual lectures, and augmented reality (AR) (Kellems et al., 2019; Khan et al., 2019; Savelsbergh et al., 2016; Yot-Dominguez & Marcelo, 2017). Specifically, augmented reality (AR) has been deemed as a promising innovation that paves the way for teaching and learning opportunities, enhances students' success, those with and without disabilities (Kellems et al., 2019), and it is presently transforming the interaction and engagement of people with inanimate objects (Weng et al., 2020). On the basis of research studies dedicated to the AR technology, AR can promote teaching and learning outcomes in light of achievement, attitude, confidence, motivation, interest, spatial ability, engagement and ultimately, satisfaction of students (e.g., Akcayir & Akcayir, 2017; Weng et al., 2020). The AR technology application has been generally found to enhance experiences in distinct learning environments offering learning activities (Yuen et al., 2011). Augmented reality (AR) covers an extensive range of technology projecting computer generated contents (text, images, and videos) onto real world perceptions (Yuen et al., 2011). In AR technology, a combination of the physical and virtual world is directed towards improving the environment of the user, supported by additional information in the form of camera-generated images, videos and audio through the use of computer and mobile technologies (Sommerauer & Muller, 2014). Yuen et al. (2011) presented a detailed explanation and discussion concerning AR technology and the related applications. In other studies, Akcayir et al. (2016) contended that AR technology application in the field of education has become even more feasible in the current times with new applications facilitated through computers and mobile devices making them affordable, compared to their predecessors that needed sophisticated equipment (e.g., head-mounted displays).

Through the combination of real and virtual objects, AR enables the visualization of abstract concepts and complex spatial relationships and the experiencing of phenomena in a way that cannot be experienced in the real world, and thus, reinforcing the interested towards education (Wu et al., 2013). There are several forms of AR applications like AR books, AR gaming, discovery-based learning, object modeling, skills training (Yuen et al., 2011). In AR books, the digital content is combined with physical contents through the physical book's augmentation with 3D objects, voice and elements of multimedia, enabling the mitigation of gap between the virtual and physical realm (Yuen et al., 2011). Furthermore, AR books facilitate immersive learning, in-depth understanding and encourages the motivation, participation, and engagement of learners (Chen, 2006; Shelton & Hedley, 2002). In the teaching of science such as biology, effective use of visualization methods like 3D materials, actual real-life objects, videos and other technology assist the learners to learn the abstract and invisible concepts of the subject (Cimer, 2012). AR can also be combined, with assistive or instruction technology, according to which the principles of learning design enable students with learning abilities to effectively and successfully learn (Walker et al., 2017).

In this regard, several works have explored AR technology and reported that it affects learning environment (Akcayir et al., 2016; Kellems et al., 2020). In Mc Mahon et al.'s (2016) study, the authors worked with postsecondary students suffering from intellectual disabilities, with the use of AR to instruct them on the vocabulary of science, whereas Chang et al. (2013) used AR with students with disabilities to teach them work-related skills. Chen Lee, and Lin (2015) also used the same to illustrate ways of identifying emotions, and Kellems et al. (2020) involved middle school students in their use of AR to teach mathematics. Despite the adopted teaching approaches directed towards enhancing learning achievements among students (with and without learning disabilities), works dedicated to examining students' outcomes through the use of AR technology are still few and far between, with reported inconclusive findings with regards to the effectiveness of intervention (Kellems et al., 2020; Savelsbergh et al., 2016). Prior studies have only begun to touch the potential of AR as an instructional technique, specifically with those having intellectual disabilities and as such, studies are required to examine its effectiveness when used with SLD students (Kellems et al., 2020). Furthermore, the limited studies of AR studies in light of student attitudes should be noted. According to prior studies (Kellems et al., 2020; Rega & Mennitto, 2017; Walker et al., 2017), research studies dedicated to AR as an evidenced-based approach for instructing students with special

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needs are still few and far between, and as such, the present study primarily aims to examine the viability and feasibility of using AR in textbook design for basic science in an attempt to enhance learning outcomes and to determine attitude towards basic science among students with learning disability. Hence, the present study contributes to literature on knowledge-based interventions, providing positive learning outcomes, as it examines the attitudes of students with learning disabilities towards basic science course, using AR approach, which is the first of this endeavor. This is significant as attitudes play a key role in successful integration of AR technologies in educational settings. This study sought to answer the following research question" how AR application promotes positive attitudes towards science and enhances the learning outcomes among special need students." This study hypothesized no significant differences in students' attitudes towards science and their learning outcomes between AR and the control group.

Augmented Reality (AR) in the Learning Environment

AR studies point towards its high significance in the 21st century for learners with disabilities (Kellems et al., 2020), with related technology enabling teachers to succeed in satisfying the requirements of students with disabilities by allowing them to experience the real world combined with the virtual one, all the while linking it with reality (Karamanoli & Tsinakos, 2017). Nevertheless, research focused on the use of AR interventions for students with disabilities has yet to be extensively conducted as evidenced by the recommendations of Gupta et al. (2019) and Kellems et al. (2020). Among the studies that examined intellectually challenged elementary students using AR for teaching fundamental matching skills successfully was carried out by Richard et al. (2007), while Smith et al. (2016) used AR to examine teaching navigation skills to students with the same disabilities.

In Mc Mahon et al.'s (2016) study, the authors worked with postsecondary students suffering from intellectual disabilities, with the use of AR to instruct them on the vocabulary of science, whereas Chang et al. (2013) used AR with students with disabilities to teach them work-related skills. Chen Lee, and Lin (2015) also used the same to illustrate ways of identifying emotions, and Kellems et al. (2020) involved middle school students in their use of AR to teach mathematics. Prior studies have only begun to touch the potential of AR as an instructional technique, specifically with those having intellectual disabilities and as such, studies are required to examine its effectiveness when used with SLD students (Kellems et al., 2020).

Based on prior studies, AR technology is capable of enhancing educational outcomes and achievements (e.g., Chiu et al., 2015). To begin with, Dede (2009) revealed the relevance of AR in students' engagement in explorations of the actual physical world and Klopfer and Squire (2008) evidenced it enabling the experience of scientific experiments like chemical reactions that cannot be easily experienced in the actual world. In the same way, AR was also evidenced to enable the visualization of concepts like airflow/magnetic fields, and events through the display of virtual elements over actual objects (Dunleavy et al., 2009; Wu et al., 2013).

Added to the above, Singh et al. (2015) showed that AR enhances the students' knowledge and skills and revives their educational interest, and this according to El-Sayed et al. (2011) is true more so compared to other technologies. AR boosts the motivation of the students, their gaining of optimum skills of investigation and steers clear of providing them conceptual fallacies experience (Sotiriou & Bogner, 2008). AR is unique in its visualization features (Erbas & Demirer, 2019) and it has been, time and again, proven to be an effective technology to visualize and provide concrete instances of abstract concepts (Erbas & Demirer, 2019). In the same way, Ab-Aziz et al. (2012) focused on the effectiveness of two technological trends on the learning of students in the special education classes of Malaysia and found augmented reality to benefit their process of learning. According to them, AR does provide advantages to the learning process. Moreover, AR, as a hand phone app was revealed by McMahon et al. (2016) to assist in learning science vocabulary and enhanced general vocabulary among students with disabilities. This was supported in Lin et al.'s (2016) study, who revealed that the app use among students with ADHA and reading disabilities enhanced their word recognition skills. Lastly, Almutairi and Al-Megren (2017) developed an app with AR for the teaching of Arabic to deaf primary school children. They combined video, images and audio with AR and found that teachers and parents of deaf children made effective use of many resources.

Attitudes refer to the response of individuals towards objects and conditions, generating, driving and impacting situations (Inceoglu, 1985). Attitudes refer to tendencies rather than behaviors that direct individuals to behave in specific ways (Sirakaya & Cakmak, 2018). In the context of technology, positive attitudes towards

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it directly affect its use. The attitudes of individuals towards new technology adoption differ and because of such difference, the process of integration may culminate in adoption/rejection of technologies (Akca & Ozer, 2012). According to Sirakaya and Cakmak (2018), the attitudes of students towards new technology will affect its use (effectiveness and productivity) in the classroom and hence, it becomes a must to identify the attitudes of students towards AR applications to ensure its successful use in learning. In effect, attitude towards AR is significant in making sure that it is acquired and disseminated in schools. AR is generally utilized in the education setting to positively motivate students and teachers (Sumadio & Awang, 2010) and to increase the learning experience excitement (Ab-Aziz et al., 2012). It assists abnormal kids to obtain and develop cognitive and motor skills, making education excited, fun, interactive and compelling (Dhamdhere et al., 2019). Finally, prior studies (Kellems et al., 2020; Rega & Mennitto, 2017; Walker et al., 2017), dedicated to AR as an evidenced-based approach for instructing students suffering from learning disabilities are still few and far between, and as such, the present study primarily aims to examine the viability and feasibility of using AR in textbook design for basic science in an attempt to enhance learning outcomes and to determine attitude towards basic science among students with learning disabilities. This main aim is achieved by determining the following research questions;

1. What is the attitude of students with learning disabilities towards AR application?
2. What is the effect of using AR in basic science course on the learning outcomes of disabled students?
3. Do the students who learn using AR learning approach have significantly better attitude towards learning basic science compared to those using traditional learning approach?
4. Do students in the experimental group score higher attitude scores in the pre-test compared to post-test?
5. Do students in the experimental group score higher learning outcomes in the pre-test compared to post-test?

Research Methodology

General Background

This research employed a quantitative quasi-experimental approach with equivalent control group pretest and posttest design (Creswell, 2014), to explore the AR effectiveness in promoting positive attitudes towards science and enhancing the learning outcomes among 6th grade special needs students. The students were selected from the schools following Jordanian Ministry of Education (MoE). The survey was used as it has been generally used to determine characteristics like views, abilities, beliefs, attitudes, expectations, and thoughts (Jdaitawi, 2020; Creswell, 2012; Fraenkel & Waleen, 2006; Sirakaya & Cakmak, 2018; Jdaitawi, 2020). According to Buyukozturk et al. (2008), survey studies primarily aim to present the case under study. The study group consisted of 24 grade 6th students in primary schools that have special needs to examine AR supported instructional experience. The students in the group were identified using purposive sampling method, where the sample is determined on the basis of the research purpose (Fraenkel & Wallen, 2006). This research used the criterion of experience in AR supported instruction to determine the study group. The instruction was provided in a span of 4 weeks divided into 4 units according to the 6th grade science curriculum of the academic year 2018/2019, using AR application. The students were categorized into two groups (AR groups and Control group).

Research Setting and Sampling

In this research, schools having students with special needs were selected in the middle government schools in the Middle governorates of Jordan. It made up of a mixture of different needs. 6th grade students were selected from several schools and were randomly assigned as the research sample. Afterword, two groups with 24 students were selected. 12 students were selected as the experimental group taught using the AR application to learn science, and the other 12 students taught using the conventional approach without AR. Thus, a total of 24 6th graders, aged 12-13, took part in this research as they were accessible and available to the researcher, as well as only 24 students were identified by the schools as special needs students. The sample is tabulated in Table 1 below. The study followed the guidelines and ethical principles stipulated by Jordanian Ministry of Higher Education & Scientific Research. Necessary permission was obtained from the schools where the research was conducted. Furthermore, the researcher informed the participants that the data will be used for the research purpose only.

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Table 1
Descriptive Statistic of the Participants

Characteristic		*N*	%
Group	AR group	12	50
	Control	12	50

Research Instruments

This research used learning outcomes test and Augmented Reality Applications Attitude Scale on primary school students to collect data. With regards to Augmented Reality Application Attitude Scale, it was adopted from the study by Kucuk et al. (2014) to determine the students' attitudes towards AR application in their learning process, with 15 items categorized into three factors, each containing items. Prior studies used the scale and confirmed its reliability and validity (Kucuk et al., 2014). The scale measuring attitude contains three factors, namely satisfaction from use, anxiety to use and willingness to use, and they were measured using 15 items along a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Moving on to learning outcomes scale, the scale was adopted and developed based on several studies, namely Astuti et al. (2019) study, Di-Serio et al. (2013), and Mundy, Hernandez and Green's (2019) study. This scale was used to identify the knowledge levels of students with learning disabilities and their cognitive and effective outcomes relating to the process of learning. There were 11 items measured on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Validity and Reliability

The original version of research instruments was developed in English, since students who participated in this research are native language being Arabic, the instruments were translated and validated translators for Arabic speaking students. However, the instruments were translated by two bilingual speakers who are specialists and a PhD holder. The translated version was given to 5 educational experts for instrument validations, most of them working at the university and some with special needs students. The experts highlighted some issues, and their feedbacks were accepted and incorporated and were corrected accordingly. The scale's internal consistency reliability was found to be .81, indicating that it is a valid and reliable scale used to assess the attitudes among primary school students with learning disabilities towards the use of AR applications. The calculated internal consistency reliability coefficient of the scale was revealed to be .73, indicating its validity and reliability in assessing primary school students with learning disabilities towards AR applications usage.

AR Learning Material

Students' attitudes towards AR applications in educational environments were determined by providing them with the experience in a span of 4 weeks through 8 lessons in 6th grade, with the aim of providing students and teachers with 3D displays of science lessons using school lab. AR application was developed by taking the acquisitions an activity of the "Space" unit included in the 6th grade science class, based on the activities in the textbook. Initially, in this study, the research obtained the opinions and feedback of 2 field experts, 2 teachers and 3 technical experts during the process of the AR application development. The study conducted pre-test and post-test evaluation. There were 24 students with disabilities at the schools. In a ten-minute pre-test organized in the first day, students were given a question to answer without access to any information material or reference classes. Next, they were given the questionnaire related to the study variables. Then, the students were split into two groups. The first group was a control group and the teacher taught them using traditional method, which began by explaining the main ideas and supportive activities and ending by assigning assignment and discussion. The second group was exposed to AR classes in their learning activity. The AR classes were introduced into several lessons in science curriculum. The introduction lesson involved assistant from the teacher as a moderator to demonstrate the activity to students and detailing their difficulties in the subject's context in the form of a visual. Then the students would

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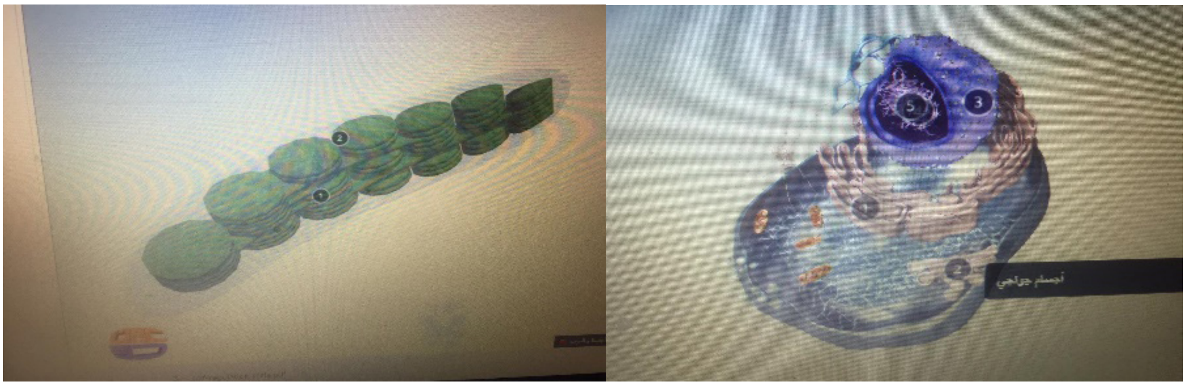
have to repeat the activity without assistance. Then the teacher introduced AR activity to make the topic easier. For each task, participants were accompanied by after the learning activities, the post-test questionnaires were distributed to students for completion. Experimental groups were taught using AR application. Figure 1 showed the activities performed in the AR application.

Figure 1
The AR Activity used in the Study



Data Collection

This research used learning outcomes test and augmented reality applications attitude Scale on primary school students to collect data. With regards to augmented reality application attitude scale, it was adopted from the study by Kucuk et al. (2014) to determine the students' attitudes towards AR application in their learning process, with 15 items categorized into three factors, each containing items. Prior studies used the scale and confirmed its reliability and validity (Kucuk et al., 2014). The scale measuring attitude contains three factors, namely satisfaction from use, anxiety to use and willingness to use, and they were measured using 15 items along a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale's internal consistency reliability was found to be 0.81, indicating that it is a valid and reliable scale used to assess the attitudes among primary school students with learning disabilities towards the use of AR applications.

Moving on to learning outcomes scale, the scale was adopted and developed based on several studies, namely Astuti et al. (2019) study, Di-Serio et al. (2013) study, and Mundy, Hernandez and Green's (2019) study. This scale was used to identify the knowledge levels of students with learning disabilities and their cognitive and effective outcomes relating to the process of learning. There were 11 items measured on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The calculated internal consistency reliability coefficient of the scale was revealed to be .73, indicating its validity and reliability in assessing primary school students with learning disabilities towards AR applications usage.

Data Analysis

The data was examined for checking the normality (Skewness and Kurtosis and outlier Mahalanobis) cases using several indicators such as (Judd et al., 2017; Tabachnick & Fidell, 2007). However, the results proved to be normal and outlier cases were identified. Descriptive statistics such as mean *M* and standard deviation *SD* and other statistical tests such as independent sample *t*-test, ANOVA and ANCOVA were involved in this study to identify the possible mean differences between the AR group and control group.

Research Results

Prior to testing the hypotheses (there is no significant difference in the learning outcomes posttest in science course between AR group and control group), the independent sample T-tests were conducted on the independent samples to identify the statistical equivalence of the groups. The dependent variables included are

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learning outcomes and attitudes towards science. In the initial set of statistical tests, the difference between the experimental and control groups in pre-test learning was obtained based on the level of significance (.05). From the result, insignificant differences in t-test were found between the groups based on pre-test of learning outcome scores (F = .003, p = .955, t = .543, p = .599), but F-test for the equal variance was significant. The mean score of the total pre-test sample of learning outcomes is (M = 2.60), with standard deviation of (SD = 0.307). In order to control the significant differences between the groups in the pretest result, ANCOVA analysis was conducted. The analysis was run for the variable learning outcomes of the groups and for the first set of analysis, significant main effects were found for student groups with the dependent variable; for the experimental group the mean square was (value = 3.514, F =17.840, p = .0001 <.05) as shown in table 3. The experimental group showed higher scores for total learning outcomes with a (M = 3.63, SD = 0.481), compared to its controlled counterpart that had a mean of (M = 2.87, SD = 0.380) as shown on table 4.

Table 2
Summary Statistics for Learning Outcomes Variable Pre-test Scores

Variable		Experimental	Control	Total
Learning Outcomes	*M*	2.63	2.56	2.60
	SD	.300	.324	.307

Table 3
Results of ANCOVA for Between-Subjects Effect of the Learning Outcomes Post-test

Source	*MS*	*df*	*F*	p
Corrected Model	1.758	2	8.928	.002
Intercept	3.124	1	15.863	.001
Group	3.514	1	17.840	.001
Learning Outcomes Pretest	.004	1	.020	.889
Error	4.136	21		
Total	261.744	24		
Corrected Model	7.653	23		

p<.05

Table 4
Summary Statistics for Learning Outcomes Variable Post-test Scores

Variable		Experimental	Control	Total
Learning Outcomes	*M*	3.63	2.87	3.25
	SD	.481	.380	.576

To determine the statistical equivalence of the groups in the second hypothesis (there is no significant difference in the students' attitudes post-test towards science course between AR group and control group), the independent samples were exposed to independent sample t-test prior to hypotheses testing. In the first statistical test, the difference between experimental and control groups based on their pre-test attitudes towards science was identified based on .01 level of significance. The t-test results supported insignificant differences between the groups (F = .906, p .351, t = 1.227, p=.233). The post-test scores of the two groups in terms of attitudes towards science indicated significant differences, with the following result for the experimental group ($F = 3.159$, p = .089, t = 2.372, p = .027 < .05) as shown in table 5. The mean score of attitudes in the control group (M = 2.78, SD =0.527) is relative to the experimental group (M = 3.20, SD = 0.304) as presented in table 6.

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Table 5
Results of Independent Sample t-test for Variables Attitudes towards Science Post-test

Variable	*F-value*	*Sig. value*	*t*	*df*	*p*
Attitudes towards Science	3.159	.089	2.372	22	.027

Table 6
Summary Statistics for Attitudes towards Science Variable Post-test Scores

Variable		Experimental	Control
Attitudes towards Science	*M*	3.20	2.78
	SD	0.304	0.527

Based on the results of the ANOVA test, significant differences existed between the groups in light of their attitudes towards science. ANOVA results showed the experimental group to obtain the following values (MS = 1.042, F = 5.626, p = .027 < .05).

Table 7
Results of ANOVA for the Effect of the Attitudes towards Science Post-test

Source	Sum of Squares	Mean *df*	Square	*F*	*p*
Between Group	1.042	1	1.042	5.626	.027
Within Group	4.074	22	.185		
Total	5.115	23			

p < .05

Moving on with testing of the test difference hypothesis (i.e., there is no significant difference in the level of pre-test and post-test attitude scores among experimental groups), the study carried out paired sample t-test to determine whether there is a significant mean score of the students with special needs attitudes in the pre-test and post-test scores. The overall attitude in pre-test mean score was found to be (M = 2.45), with standard deviation of (SD = 0.459), while the overall attitude in post-test mean score was (M = 2.99), with standard deviation of (SD = 0.471) as shown in table 8. The mean score increased based on the pre-test and post-test mean scores.

Table 8
Summary Statistics for the Experimental Group Attitudes Towards Science Scores

Variable		Post-test	Pre-test
Attitudes towards Science	*M*	2.99	2.45
	SD	0.471	0.459

The research conducted a comparison of the overall mean square using the paired sample t-test and it was found to be significant at (t = 4.666, df = 23, p = .01), with a difference of (.544), indicating a significant increase (p = .05) in the experimental group's mean in light of the attitude of the students towards science as shown in table 9.

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Table 9
Results of Paired Sample t-test for Variable

Variable	*t*	*df*	*p*
Attitude towards Science			
Experimental group	4.66	23	.001

Moving on with testing of the (i.e., there is no significant difference in the level of pre-test and post-test earning outcomes scores among experimental groups), paired sample t-test was carried out to know if the mean score in the learning outcomes of students was significant based on pre-test and post-test scores. The overall learning outcomes of the experimental group's pre-test had a mean of (M = 2.60), with standard deviation of (SD = 0.307), while in the post-test the mean was (M = 3.25, with standard deviation score of (SD = 0.576) as displayed in table 10, indicating increased scores following the implementation of learning technique.

Table 10
Summary Statistics for the Experimental Group Learning Outcomes Scores

Variable		Post-test	Pre-test
Learning Outcomes	*M*	3.25	2.60
	SD	0.576	0.307

The research compared the overall mean score of the pretest and posttest for the experimental group using paired sample t-test, after which it was found to be significant at t (4.842, df = 23, p = .01), with a mean score difference of (.651), and a significant increase of (p = 0.05). The detailed results are presented in table 11.

Table 11
Results of Paired Sample t-test for Learning Outcomes Variable

Variable	*t*	*df*	*p*
Learning Outcomes			
Experimental group	4.842	23	.001

Discussion

The aim of this research was to examine the AR application's effectiveness in the attitude of primary school students suffering from learning disabilities, towards basic science, and to identify the different effects of AR technology on their learning outcomes. The AR application development had its basis on the science teaching material specified in the research framework and the development was made under the feedback of field experts, technical experts, and teachers. Prior to collecting data, students were instructed on basic science lessons in the span of two weeks through AR technology, which basically provided them a learning experience through it. Based on the results, the students with learning disabilities showed a positive attitude towards the application during the instruction. AR essentially facilitated a positive environment in the classroom that is distinct from the traditional classroom, which was assumed to promote the positive attitude of students towards learning basic science. The research results showed that AR application assisted in the students' development of positive thoughts about science lessons and in enhancing their attitudes towards their learning environment. In other words, the use of AR technology benefited the educational environment and provided interactive and proactive learning environment through reality enhancement (Sirakaya & Cakmak, 2018). According to literature findings, AR teaching material provided positive contributions to the level of attitudes, willingness, enthusiasm, moti-

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vation, self-confidence, academic achievements and persistence and readiness of students. Lack of evidence concerning the direct contributions of AR to students with special education needs did not negate them. This highlights the contribution of technology-centered environments in education (Alghabban et al., 2017; Ayres et al., 2009; Bakker et al., 2016).

To begin with, Akir and Korkmaz (2019) showed that AR technology materials enhanced the interest of students with special needs towards the studied subject, and Delello (2014) revealed that AR technology improved the student's interest towards lessons. AR application also improved the interest of students and directed it towards materials of learning (Ibili & Sahin, 2013), which significantly heightened their attention towards learning, particularly students with vision and hearing problems, retarded growth and behavioral problems, and those with special education needs (Cakir & Korkmaz, 2019). In the same line of study, AR assisted students to learn more easily and more effectively, increasing their interest towards learning procedures (Ho et al., 2011). The findings indicated significant differences between students exposed to AR technique of learning and conventional learning, and the total score of attitudes towards basic science subject also had significant differences between the two groups, with the AR group being higher. This is indicative of the fact that AR application usage could be effective in enhancing the interest and attitudes of students with learning disabilities. This was supported by Chen et al.'s (2016) finding that showed AR to be capable of assisting students with ASD to display their feelings and status and be aware of different circumstances. Also, Pradibta (2018) revealed the way AR enlightened the students learning and directed their attention towards the learning process, while Karamanoli and Tsinakos (2016) revealed the advantages that AR tool can provide students in terms of transforming their learning process to a more stimulated and entertaining process. It paved the way for dyslexic students to be more interactive while learning and gaining new experiences. The findings of this research are in line with that of prior studies in literature, where students suffering from disabilities can be made more inclined towards learning in a technology enriched classroom surrounding.

Learning Outcomes

The findings of this research revealed that students with special needs enhanced their learning outcomes through the AR application used for basic science lessons. AR technology usage significantly affected the outcomes of students' learning, indicating that the use of such technology was an effective tool, particularly when used with disabled students. Notably, AR supported the learning outcomes of the students in a way that traditional classroom was not able to. In the same line of study, Delello (2014) stated that AR had a key role in the learning of students, urging their participation and interaction in class and enabling their deeper understanding of subjects. AR technology was thus an effective support learning and teaching tool in the education realm (Hsu, 2017; Tian et al., 2014), through the advantages reaped from it. In addition, AR technology was capable of easing learning among students and their understanding of the content material, which in turn, affected their learning capabilities. It familiarized students with the study and its activities boosting their interaction in the process of learning. In fact, Karamanoli and Tsinakos (2016) indicated that AR enhanced the learning activities provided to students, especially those with learning disabilities from simple and static to interactive. The differences in pre-test and post-test may be attributed to the visual support learning mentioned in Cimer's (2012) study. AR technology facilitated visual-aided learning and teaching, where students could easily learn through visual aids. It also facilitated the participation of the students, their concept retention through the tools (visual and audio), promoting their connection of ideas and concepts.

According to the research findings, significant differences were found between the two groups in light of learning outcomes, using learning materials provided by AR technology in a way that AR technology affected such outcome among dyslexic students in the experimental group. Literature generally found significant effects of AR technology on learning outcomes for students (with and without learning disabilities) in many ways, enabling them to benefit from its educational contributions (e.g., Bacca et al., 2014; Kellems et al., 2020; Lorenzo et al., 2019; Radu, 2014). There are several reasons cited in literature as to the use of AR in learning and they include flexibility in instruction designs, support of spatial visualization/audio, enhancement of communication skills, enrichment and provision of meaningful learning and transference of knowledge (Cakir & Korkmaz, 2019). AR provides interaction with a 3D view of the object from different angles that enhances the students' skills and abilities as well as provides them with the skills to practically apply the object (Cheng & Tsai, 2013; Hsiao & Rashvand, 2011). AR technology further provides timely feedback in real-time interaction, leaving the control

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of learning in the students' hands (Bujak et al., 2013; Kucuk et al., 2015; Yuen et al., 2011) and AR technology is basically a combination between virtual and real world elements established in a single environment through images, data and real world contents (Solak & Cakir, 2016). The need for AR technology has been highlighted in literature with several studies indicating the requirement of using visual teaching and learning materials and contents (multimedia design and computer simulations) to assist the understanding of concepts (Cimer, 2012; Mayer, 2009). The use of AR multimedia among children suffering from ASD to enhance their communication skills, was examined in Taryadi and Kurniawan's (2018) study. The authors reached to the conclusion that PECS generated a development of communication ability among the children when comparing pre-test and post-test scores. In the same way, Lorenzo et al. (2019) examined the effectiveness of AR in enhancing the social skills of 11 autistic children. Based on the reported results, the students in the experimental group displayed enhanced social schools but insignificant differences were revealed. In addition, Kellems et al. (2020) dedicated his recent study to investigating the AR effectiveness in teaching mathematics to middle school students that had learning disabilities. The students obtained good scores, with improved problem-solving skills after the intervention.

Moreover, Yalcinkaya (2012) maintained that the development of social skill education in the computer environment fitted with web-based distance education system among children with mild mental disabilities. The children participated in various activities (e.g., drawing on a drawing tablet, shooting short videos within the planned framework, participating in technology-enriched extracurricular activities). Based on the research's results, extracurricular activities driven by technology had a positive influence on the students' cognitive and physical development. Meanwhile, Dogan's (2015) study on the effects of technology-supported extracurricular activities on students that had mental disabilities reached to the conclusion that such activities positively affected the students' cognitive and physical development. Also, Dunleavy et al. (2009) highlighted the potential of AR in enhancing learning among students, with its distinct ability to develop immersive hybrid learning environments, which facilitated the development of the students' critical thinking, problem solving and communication through collaborative exercises. Furthermore, AR was integrated in communication interventions through the connection of elements of augmented and alternative communication and applied behavior analysis strategies (STAR) in the research by Almeida et al. (2015). AR also managed to improve the students' memory and social skills. From the above findings in literature, the present study's investigation is justified.

Conclusions and Suggestions

The augmented reality (AR) technology has proven suitable for school environment. Promising innovation paves the way for teaching and learning opportunities and enhances students' success. AR technology contributes effectively towards achieving optimum results when using AR instruction, one of the best learning methods for students with special needs. It supports the inclusion of students and instructors in selecting the right and most effective instructional method, to enhance the learning outcomes and to ensure that students have the opportunity to express positive attitudes, increased interest, focus, attention and interaction. The natural usage of AR technology in learning is crucial as the AR is a combination of the physical and virtual world which is directed towards improving the learning environment through providing more visual and audio information through the use of computer and mobile technologies. The combination of real and virtual objects, AR enables the visualization of abstract concepts and complex spatial relationships and the experiencing of phenomena in a way that cannot be experienced in the real world, and thus, reinforcing the learning experience, increasing understanding, and enhancing student's motivation, participation, and their engagement. Utilizing the AR technology in the special needs learning process, students could be better engaged in learning. They could also participate in the learning world via their positive attitudes towards science, thus increasing the demand for science and technology-related majors and careers. The findings of the present research provide vital information for instructors and academicians intending to move towards effectively implementing AR technology in their learning process for students with special needs. Although, previous research dedicated to AR as an evidenced-based approach for instructing students with special needs are still few and far between, and as such, in this work, AR instruction is tested using 6th grade students in their science curriculum. The present research's examination is focused on whether grade 6th students with special needs could determine an instruction method in advance that would lead to the most optimum learning, therefore, more research is needed in other students' ages and courses. The research's sample does not promote generalization of results to the general population

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of students with special needs, as the research results are based on the participating students in the study. Hence, the sample of the research should be extended to other students. Regardless of the enhanced evidence of the mean scores of the students, the research experiment spanned only 4 weeks and thus, a longer period of research is needed for conclusive results. The research is also limited in its data collection method, which is the self-report measures, as this is characterized by inflated biases, influenced by the existing social desirability. Thus, this research recommends that future authors investigate the research objectives through the use of mixed method approach (quantitative and qualitative methods).

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DETERMINANTS OF SCIENCE TEACHERS' HEALTHY EATING BEHAVIORS: COMBINING HEALTH BELIEF MODEL AND THEORY OF PLANNED BEHAVIOR

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Abstract. *This study was conducted to provide a comprehensive understanding of determinants of science teachers' healthy eating intentions and behaviors by combining the health belief model and the theory of planned behavior into one conceptual framework and considering the mediating impact of attitude and intention on behavior. This study was conducted based on cross sectional study design between November 2019 and February 2020. A total of 13 hypotheses were tested and data collected from 563 science teachers in Turkey were analyzed using structural equation modeling. The results of the study showed that the proposed model explained the variance in intention and behavior at a more satisfactory level than existing theories. The results also revealed that all of the hypotheses were supported. In addition, the mediating role of attitude and intention in understanding science teachers' healthy eating behaviors was identified. The study can provide important implications for education stakeholders, curriculum developers and science educators.*

Keywords: *health belief model, healthy eating behavior, science education, theory of planned behavior*

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Introduction

Healthy eating is a major behavioral factor for dealing with obesity and non-communicable diseases such as some types of cancer, cardiovascular disease, and type-2 diabetes (World Health Organization; WHO, 2016) accounting for 71% of the worldwide mortality rate (WHO, 2018). In addition, the number of people who undernourished increased from 784 million to 821 million between 2015 and 2017 (UN, 2019). Thus, the implementation of a healthy eating should be encouraged. WHO (2016) expressed that a healthy eating should include small amounts of saturated fat, salt and refined carbohydrates, as well as high consumption of fruits, vegetables and whole grains. Recent data in Turkey have indicated that people do not care about their healthy eating behaviors. For example, the proportion of obese individuals was 15.2% in 2008, while it increased to 19.6% and 21.1% in 2016 and 2019, respectively (Turkish Statistical Institute, 2020).

Education of individuals is the best solution for increasing levels of problems related to healthy eating around the world since health-related topics such as healthy eating are involved in socio-scientific issues which present great opportunities for the next generations (Fensham, 2012) and has a powerful relationship with education (Kickbusch, 2001). Considering the importance of health education in socio-scientific issues, in particular, science teachers play an essential role since students are taught to decide upon related to current social issues (Zeidler et al., 2009). In addition, science teachers can be helpful by teaching basic beliefs and personal values as well as decision-making processes and by teaching the science to act health behaviors (Zeyer & Dillon, 2014). Moreover, the topics related to healthy eating may easily be integrated into science courses (Arnold, 2018) and taught by science teachers. However, to organize effective learning environments, understanding science teachers' healthy eating behaviors and its antecedents play an important role to help researchers and professionals to design influential and appropriate intervention strategies and change un-healthy eating behaviors (McEachan et al., 2011). Moreover, teachers' beliefs about healthy eating may affect the likelihood of providing health

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education or promoting healthy eating practices in the classroom and may help adjust nutrition education services and professional development to meet teachers' needs (Jones & Zidenberg-Cherr, 2015). Therefore, new studies on science education need to be examined factors affecting health behavior and allowing for the inference of useful interventions to encourage health literacy and health behaviors in science education (Arnold, 2018).

There are several behavioral theories understanding health-related behaviors such as the Health Belief Model (HBM), Theory of Planned Behavior (TPB), the Health Action Process Approach and the Framework Model of Health Literacy. Among them, HBM and TPB are the most used theories for explaining individuals' healthy eating behaviors (e.g., Ateş, 2019; Fila & Smith, 2006). Accordingly, the current study used HBM and TPB to understand science teachers' healthy eating intentions and behaviors. The most importance of TPB is that people' behavioral intentions are the determinants that best explain their behaviors (Ajzen, 1991). In the TPB, volitional and non-volitional dimensions constitute the basis of intention and behavior (Ajzen & Fishbein, 1980), while the basic premises of the HBM are threat perceptions and behavioral evaluations (Bylund et al., 2011). The proficiency of these rational theories has been tested to determine healthy eating behaviors (e.g., Kim et al., 2012; Shimazaki et al., 2017; Sun et al., 2006) and each of these theories has been shown to be useful in understanding individuals' health related decision-making process (Huang et al., 2020). However, the adequacy of these theories has often been doubted (Gerend & Shepherd 2012). Moreover, a great majority of limited number of earlier studies tested the direct effect on healthy eating behaviors, while only a few studies investigated indirect effect between constructs (e.g., Deshpande et al., 2009). Considering the insufficient number of studies, therefore, earlier researchers called for health-related studies that testing of these theories should continue to better understand the factors on healthy eating behavior (e.g., Riebl et al., 2015). It was also suggested that they converge and compare with each other to contribute more to the literature, since both the HBM and TPB alone do not completely account for complexity and multi-dimensionality of behaviors (Noar & Zimmerman, 2005). Given the lack of empirical studies that focus on combining HBM and TPB, it is needed to combine the two theories to determine particular constructs that impact specific behaviors, which will help to develop our understandings (Gerend & Shepherd 2012). Further, to the best of our knowledge, no study has investigated science teachers' healthy eating intentions and behaviors by combining two theories and proposing a theoretical conceptual framework.

To address this literature gap, the current study aimed to: a) propose a conceptual framework for understanding science teachers' healthy eating intentions and behaviors through two theories (i.e., HBM and TPB); b) determine the relative importance of the proposed model compared to the HBM and TPB; c) explore the relative importance of the constructs of HBM and TPB within the proposed model to understand the intention and behavior; d) examine the mediating role of attitude and intention on healthy eating behaviors.

Literature Review and Hypothesis Development

Science Education and Health Education

Health education has been increasingly significant context for science education (Zeyer & Dillon, 2014) and accepted as fundamental dimension of scientific literacy (Zeyer & Kyburz-Graber, 2012) since health is intimately connected with human lives (Cruz, 2009). In addition, health topics occupy an important place in science education, as scientific facts and principles are very important in understanding biological systems (Arnold, 2020). Moreover, science educators advocate that the necessary education should be given at the school in order to create awareness in students against misleading information about health-related behaviors such as healthy eating (Fine et al., 2013). However, experts in the field stated that health issues are neglected in science education (e.g., Harrison, 2005; Zeyer & Dillon, 2014). For example, in US, there is no prepared health curriculum that can be used nationwide, and, in this vein, health is presented as a separate topic, regardless of science and health education emphasizes basic subjects about health issues (Keselman et al., 2012). However, in recent years there are some initiatives related to including health to science education. Attempts have been made to link health issues with science education, socio scientific issue and decision-making process in science curricula in several countries (e.g., the Australian Curriculum for Science in Australia (ACARA), 2013; Turkish Middle School Science Curriculum, 2018). In addition, in the last decade, some attempts have been done to explain the importance of this relationship (e.g., Arnold, 2018, 2020; Zeyer & Dillon, 2014). For example, a book called "Science | Environment | Health: Towards a Renewed Pedagogy" was published in 2012 to provide well-grounded perspectives on how science education can take advantage of the challenges of health education (Zeyer & Kyburz-Graber,

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2012). In the light of the information obtained from this book, the relationship between health education and science education can be summarized as indicated below.

a) Health issues can help strengthen students' interest and motivation for science education.
b) Health education and science education can encourage informed citizenship and well-informed personal choice regarding health.
c) Incorporating health issues into science education can help promote scientific literacy.
d) Health education and science education play important role in teaching socio-scientific issues.
e) Health and science literacy both are inherently knowledge-based.

Merging of HBM and TPB and Hypotheses Development

As stated earlier, unhealthy eating and poor dietary habits such as non-consumption of vegetables and fruits, skipping breakfast, excessive weight gain, and consuming a lot of fast food (Laska et al., 2012) would conclude negative effect on the health of individuals in the short term or long term. Therefore, paying attention to individuals' eating behaviors can be considered vital to living a healthy life in terms of pro-self and pro-social concerns, since understanding the determinants of eating behaviors is regarded as an important area of research that reduces both the individual and the society. Accordingly, many researchers used the TPB and HBM to understand individuals' healthy eating behaviors. The TPB and HBM are based on expectancy-value framework (Brewer & Rimer, 2008) and suppose that healthy eating behaviors are related to deliberative and rational process in consequence of personal utility and costs (Brewer & Rimer, 2008; Conner & Sparks, 2005). Therefore, both theories focus on voluntary and non-voluntary processes, which are accepted as basic factors of rational choice theories in explaining healthy eating behaviors. However, TPB assumes that intention is influenced by attitudes, subjective norms, and perceived behavioral control (PBC), while HBM embody conflicting values, perceptions, and social interactions (Wheeler, 2008) and emphasize the importance of the influence of health beliefs on behavior (Janz & Becker 1984). However, both TPB and HBM contain overlapping variables and stress the importance of different types of beliefs in understanding human behavior. Thus, it is important to merge the two theories to determine certain variables that affect certain specific that will develop understanding related to risk prevention behaviors (Gerend & Shepherd 2012). Further, combining constructs of TPB and HBM may provide a better accountability to understand healthy eating intentions and behaviors than research that simply adopted the model or framework and may develop the explanatory power of the combined proposed model. For example, Gerend and Shepherd (2012) revealed that when tested separately, HBM and TPB accounted for 26 and 39 % of the variance in health-related behaviors, respectively, while merging HBM and TPB increased the explanatory power of the merged model by 4%. Accordingly, as often suggested in past studies (e.g., Gerend & Shepherd, 2012; Huang et al., 2020), this study postulated a proposed model that a merging TPB and NAM in one theoretical model can best explain healthy eating behaviors.

Health Belief Model

For nearly 70 years, the HBM has extensively used conceptual model as a guiding theoretical model for health-related behavioral interventions (Champion & Skinner, 2008). The HBM was developed originally in the 1950s to understand whether people attend preventive programs to prevent and determine diseases (Becker & Maiman, 1975).

The initial theory posits that health-related decision-making process is based on primary concepts including threat perceptions (perceived susceptibility and a perceived severity), behavioral evaluations (perceived benefits and perceived barriers) and cues to action (Bylund et al., 2011). Among the threat perceptions, perceived susceptibility is people's beliefs about the "*likelihood of getting a disease or condition*" and perceived severity is "*feelings about the seriousness of contracting an illness or of leaving it untreated include evaluations of both medical and clinical consequences (for example, death, disability, and pain) and possible social consequences (such as effects of the conditions on work, family life, and social relations*" (Champion & Skinner, 2008, p. 47). Furthermore, perceived benefits, one of the behavioral evaluations, can be defined as "*potential advantages of engaging in the health behavior, including the behavior's perceived efficacy in preventing the undesired outcome*" (Gerend & Shepherd, 2012, p.172) and perceived barriers are beliefs people have about "*the difficulties or hindrances associated with a target behavior*" (Orji et al., 2012, p.15). One of the other components of HBM is cues to action

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which are specific triggers that generate an individuals' sense of need for action (Champion & Skinner, 2008). Later, Becker and Rosenstock (1987) added the concept of self-efficacy, which is derived from social cognitive theory and defined as *"the conviction that one can successfully execute the behavior required to produce the outcomes"* (Bandura, 1997, p.204). In the HBM, self-efficacy reflects an individuals' reliance in her/his ability to act the health behavior (Weinstein, 1993). The predictive power of HBM has been strengthened with the inclusion of self-efficacy (Buglar et al., 2010).

Earlier empirical studies showed that the HBM is the most relevant explanatory theoretical model when examining the motivations for engaging in health behavior (Urbanovich & Bevan, 2020) and widely used to understand various health related behaviors, such as healthy eating behaviors (e.g., Deshpande et al., 2009), organic food consumption (e.g., Yazdanpanah et al., 2015), healthy risk preventative behavior (e.g., Huang et al., 2020) and human papillomavirus vaccine uptake (e.g., Gerend & Shepherd 2012). Among them, determinants of healthy eating behaviors have been tested by a few of previous studies. These studies revealed the importance of the constructs of HBM including perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action and self-efficacy on healthy eating intentions and behaviors. For example, Kim et al. (2012) found that college students' perceived severity, perceived benefit and perceived susceptibility were positively related to healthy eating intention, while a negative relationship was found between perceived barrier and healthy eating intention. In another study, Deshpande et al. (2009) found that healthy eating intentions of college students were predicted as positive by self-efficacy and as negative by perceived barriers. However, it was reported that perceived benefit did not have a significant influence on likelihood to eating healthy. In a study conducted with adult consumers, Cook (2018) found that among the constructs of HBM, perceived barrier was negatively related to healthy eating intention. In a study conducted with adult consumers, Orji et al. (2012) found that all the constructs of HBM were positively associated with healthy eating behavior except perceived barrier which was the only construct that affects healthy behaviors negatively.

Accordingly, a limited number of past studies confirmed that the constructs of HBM model played an important role to explain healthy eating intentions and behaviors. These studies reported that only perceived barriers are negatively associated with healthy eating behaviors since barriers such as knowledge, time and resource cannot be controlled by individuals and therefore may affect negatively behaviors (Gao et al., 2017). In other words, if individuals have higher control over healthy eating behaviors, their intentions to perform the behaviors will be stronger. Similarly, if a person feels easy and has relevant knowledge level and skills to eat healthily, he/she will probably intend to eat healthily. In addition, past studies reported that in case appropriate beliefs including that perceived susceptibility, severity and benefit are held, it triggers healthy eating behaviors (Vassallo et al., 2009) and different types of cues such as media campaign and social influence have an impact on healthy eating behaviors (Orji et al., 2012). However, the results of earlier studies conducted in different contexts may be less generalizable to the participants of the study, namely science teachers. Therefore, it is thought that the current study will make important contributions to the literature since there are a limited number of studies and the research aimed to study with individuals who have different cultural and educational levels. Based on the arguments, then we propose following hypotheses:

H1: Perceived susceptibility is positively related to healthy eating intentions.
H2: Perceived severity is positively related to healthy eating intentions.
H3: Perceived benefit is positively related to healthy eating intentions.
H4: Cues to action is positively related to healthy eating intentions.
H5: Perceived barrier is negatively related to healthy eating intentions.
H6: Self-efficacy is positively related to healthy eating intentions.

Theory of Planned Behavior

The theory of planned behavior (TPB; Ajzen, 1991) is extension of the theory of reasoned action (Ajzen & Fishbein, 1980) by adding a new construct called perceived behavioral control (PBC) which is non-volitional factor (Ajzen, 1991). The theory was proposed to reveal factors affecting various types of human behaviors (Conner & Armitage, 1998). According to TPB, the best predictor of human behavior is intention which is considered the motivational construct that encourages a person to engage in a certain behavior and intention is affected by attitude, subjective norm and PBC (Ajzen, 2005). Attitude refers to positive or negative evaluation of a certain behavior implying that the more positive attitudes towards behavior, the more likely it is to carry out this be-

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havior (Ajzen, 2005). Subjective norm defined by Ajzen (1991) as "*the perceived social pressure to perform or not to perform the behavior*" (p. 188) is people's perceptions related to the views that salient references, including family, relative, friend, and colleague, have on their behaviors. PBC is "*perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles*" and it is supposed to indicate *"past experience as well as anticipated impediments and obstacles"* (Ajzen, 1991, p. 188).

TPB is a widely used parsimonious model and the effectiveness of it in explaining various behaviors has been confirmed in a variety of health-related behaviors such as healthy eating behaviors (McEachan et al., 2011). Its popularity is partly due to its open operationalization with guidelines on how to measure, analyze and develop health interventions using theory (Ajzen, 2006). Empirical findings in earlier studies confirmed the positive relationships among attitude, subjective norm, PBC indicating the importance of the constructs in the TPB in explaining decision-making process of individuals related to healthy eating intentions and behaviors (e.g., Ateş, 2019). Previous studies have generally focused separately on specific sample groups such as children (e.g., Bazillier et al., 2011), adolescents (e.g., Chan et al., 2016; Grønhøj et al., 2013), and adults (e.g., Brouwer & Mosack, 2015). In addition, a majority of them aimed to understand healthy eating intention, while a few studies focused on understanding antecedents of healthy eating behavior. For example, Bazillier et al. (2011) tested the essential role of children' (aged 8–9 years old) attitude, subjective norm, and PBC in explaining their healthy eating intentions. They reported that attitude, social norms and PBC accounted for 35% of the variance in healthy eating intention and PBC was the most important predictor of intention. Grønhøj et al. (2013) revealed that perceived ease related to healthy eating behavior was the most influential determinant of adolescents' intentions towards healthy eating. In another study conducted by Fila and Smith (2006), the efficacy of the TPB was tested to predict healthy eating behaviors of Native American youths aged between 9–18 years old, it was found that subjective norm was the most predictive determinant. However, it was reported that there was no significant relationship between intention and behavior. Brouwer and Mosack (2015) studying with adult individuals revealed that PBC was the most influential factor on healthy eating behaviors. Among the limited number of studies conducted on teachers, Ateş (2019) studied with various elementary school teachers including Turkish language, mathematics, physical education, and classroom teachers and found that PBC was the strongest influence on both intention and behavior. Furthermore, positive association was found between healthy eating intentions and behaviors.

As a result, although past empirical studies contributed significantly to the literature, it is not clear which variable has a large impact on intention or behavior and, there are very few studies that specifically examine its effect on behavior. Moreover, since the studies are conducted with individuals of very different ages, cultures, income, social environment, and professional fields, there is a need to research the healthy eating behaviors of science teachers who will raise future generations as science literate and health literate individuals. Therefore, the following hypotheses were formulated:

H7: Attitude is positively related to healthy eating intentions.

H8: Subjective norm is positively related to healthy eating intentions.

H9: Perceived behavioral control is positively related to healthy eating intentions.

H10: Healthy eating intentions are positively related to healthy eating behaviors.

The Relationship Between Beliefs and Attitude

Many of contemporary social psychologists argue that cognitive or information processing approaches play a major role in forming attitude (Ajzen, 1991). One of the approaches is expectancy-value model developed by Fishbein and Ajzen (1975). The model proposed that attitudes develop rationally from beliefs people have about the object of the attitude and each belief ties a behavior to a specific result or another trait that occurs through the performance of the behavior (Ajzen, 1991). Since the attributes associated with behavior are already evaluated as positive or negative, we inevitably have an attitude towards the behavior (Ajzen, 2005).

Similarly, in the context of this study, we believe that health related beliefs including perceived susceptibility, perceived severity and perceived benefits affect attitude toward healthy eating and trigger the behavior. Perceived susceptibility reflects people's beliefs about the likelihood that a person will experience the outcome while perceived severity belief is to what extent people believe a health situation harmful (Orji et al., 2012). Accordingly, perceptions of susceptibility and severity can affect attitudes toward the health-related behavior (Zhang et al., 2018). Moreover, perceived benefits concern an individual' belief in targeted behavioral ability to decrease the likelihood of being influenced by the health threat (Champion & Skinner, 2008). Thus, people who

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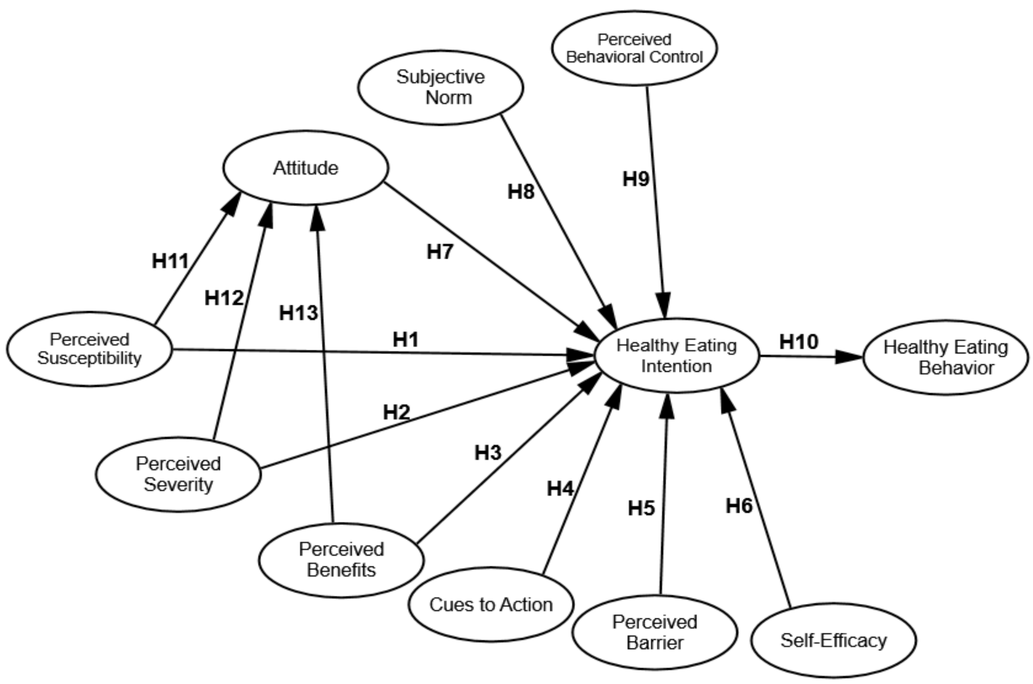
thought that the particular behavior is safer and more effective maintain a positive attitude toward this behavior (Rogers, 2010). Earlier studies confirmed the important role of perceived susceptibility, perceived severity and perceived benefits on attitude toward health-related decision-making processes (e.g., Zhang et al., 2018). For example, Zhang et al. (2018) reported that health related benefit and risk perceptions were significantly associated with attitudes. In another study conducted by Huang et al. (2020) it was found that perceived susceptibility and perceived benefit play a fundamental role on attitudes toward health, health-related preventative behaviors. However, within our knowledge, no study was conducted examining the influence of perceived susceptibility, perceived severity, and perceived benefits on attitude toward healthy eating. Therefore, in this study context, we suppose that science teachers who think that they are more likely to be exposed to risk or perceive the seriousness of the risk will have a more favorable attitude towards engaging in healthy eating behaviors. Based on the importance of beliefs on attitude as suggested in the TPB and expectancy-value model and earlier study findings, following hypotheses indicated in Figure 1 are presented:

H11: Perceived susceptibility is positively related to attitude toward healthy eating.

H12: Perceived severity is positively related to attitude toward healthy eating.

H13: Perceived benefit is positively related to attitude toward healthy eating.

Figure 1
The Proposed Model



Research Methodology

The design of the study was based on the hypothesis that, healthy eating intentions and behaviors of Turkish teachers could be explained by means of the HBM and the TPB theoretical models and theories. Depending upon this above-mentioned hypothesis, the study was conducted using cross sectional study design since data are collected from a sample that is from a pre-determined population (Fraenkel et al., 2012). Data of this study were collected on a volunteer basis between November 2019 and February 2020. The data analysis was conducted through path analysis to examine whether the HBM and the TPB statistically explain teachers' healthy eating intentions and behaviors.

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Participants

The participants of the study consist of science teachers in six cities located in different regions of Turkey. In the first application, the data were collected from 603 science teachers. However, due to some reasons such as items not filled in the questionnaire, multicollinearity and some participants delivering the instrument without completing it, 40 of the participants were excluded from the data. Finally, a total of 563 science teachers attended the study (age ranged from 22 to 68; M = 39.22, SD = 11.22; *MBody Mass Index*=25.12). Among the participants, 53.93% were male and 46.7% were female. Their average teaching experience was 19 years and 18.20% of them held a graduate degree. 55.13% of them were married, while 44.87% of them were single.

Healthy education was provided by science teachers at middle schools in Turkey. In the science curriculum, there are some objectives to be reached about healthy eating within the scope of the science lesson. For example, in the unit of 'Our Foods', it is aimed to create awareness in students about the types of food, healthy and balanced diet, the damages of smoking and alcohol use, and the benefits of healthy eating (Turkish Ministry of Education 2018). In addition, pre-service science teachers take healthy eating-based courses such as 'Nutrition and Health' during undergraduate education (The Higher Education Council of Turkey, 2018).

Instruments

Measurement instruments of the study were adopted from earlier studies described in the extant literature. Then, the instruments were changed to make them suitable for the current study setting. These instruments have been used extensively in many studies of theory expansion and deepening in various contexts, and the validity of such tools has been proven many times in these studies (e.g., Astrom & Rise, 2001; Brouwer & Mosack, 2015). The first version of the instruments was pre-tested and reviewed by health education and science education academicians. Minor revisions were made in accordance with their feedback (e.g., miswriting, spelling error, survey layout). The last version of the instruments consisted of demographic information queries and items of the proposed model.

A total of 11 scales and 40 items including three TPB constructs (attitude; seven items, subjective norm; three items, PBC; four items), six HBM constructs (perceived severity; three items, perceived susceptibility; two items, perceived barriers; two items, perceived benefits; four items, self-efficacy; four items, and cues to action; three items), intention (three items) and behavior (five items) are involved in the study. All the items were rated with 7-point Likert Type scale from "strongly disagree" to "strongly agree". Information related to the constructs, items and sources is presented in Table 1.

Table 1
The Items, Adoption Sources and Data of Convergent Validity

Construct	Item no	Statements	Source	Factor Loading	α	AVE	CR
Perceived Severity	PSV 1	My feelings about myself would change if I ate unhealthy	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.725	.71	.51	.76
	PSV 2	I am afraid to even think about eating unhealthy		.714			
	PSV 3	If I eat unhealthy, my entire life would change		.706			
Perceived Suscepti-bility	PS 1	My chances of eating healthy are great	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.792	.74	.64	.78
	PS 2	It is likely that I eat healthy		.813			
Perceived Barriers	PBR 1	I feel like I am not strong enough to eating healthy	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.788	.70	.59	.74
	PBR 2	Eating healthy requires adopting a new habit, which is difficult		.748			

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Construct	Item no	Statements	Source	Factor Loading	α	AVE	CR
Perceived Benefits	PB 1	I care to look attractive	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.702	.72	.57	.84
	PB 2	I care to have right weight		.788			
	PB 3	I believe that eating healthy improves the way my body looks		.774			
	PB 4	I believe that eating healthy prevents diseases		.744			
Self-Efficacy	SE 1	I feel better when eating healthy	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.711	.76	.54	.82
	SE 2	I usually eat the healthy I choose for myself		.702			
	SE 3	I am able to often eat healthy		.768			
	SE 4	I do eat the healthy that I planned		.744			
Cues to Action	CA 1	Teacher, Academic Staff or Doctor recommendations prompted me to eat healthy	Becker, 1974; Champion & Skinner, 2008; Rosenstock, 1974; Samoggia & Riedel, 2020	.739	.74	.52	.77
	CA 2	Campaigns (e.g., media: press, TV, and radio) prompted me to eat healthy		.722			
	CA 3	Family members or friends with illnesses prompted me to eat healthy		.703			
Attitude (For me, healthy eating is…)	ATT 1	Good	Armitage & Conner, 1999; Astrom & Rise, 2001; Ateş, 2019; Brouwer & Mosack, 2015	.779	.71	.53	.89
	ATT 2	Useful		.741			
	ATT 3	Cheap		.735			
	ATT 4	Pleasant		.722			
	ATT 5	Enjoyable		.712			
	ATT 6	Wise		.703			
	ATT 7	Necessary		.697			
Subjective Norm	SN 1	People who are important to me think I should eat healthy.	Armitage & Conner, 1999; Astrom & Rise, 2001; Brouwer & Mosack, 2015	.703	.77	.57	.80
	SN 2	People who are important to me would approve of my healthy eating		.788			
	SN 3	People who are important to me want me to eat healthy		.777			
Perceived Behavioral Control	PBC 1	I have control over whether or not I eat healthy	Ajzen, 2002; Ateş, 2021; Fila & Smith, 2006	.791	.79	.64	.88
	PBC 2	If I want, I can easily eat healthy.		.823			
	PBC 3	I think healthy eating is easy for me.		.812			
	PBC 4	Whether or not I eat healthy is mostly up to me.		.780			
Intention	INT 1	I intend to eat a healthy over the next week	Armitage & Conner, 1999; Astrom & Rise, 2001; Brouwer & Mosack, 2015	.713	.70	.54	.78
	INT 2	I plan to eat a healthy over the next week		.760			
	INT 3	I want to eat a healthy over the next week		.741			
Behavior	BEH 1	I mostly eat healthy foods.	Fila & Smith, 2006	.815	.75	.67	.91
	BEH 2	I eat healthy to keep me from getting diabetes		.823			
	BEH 3	I eat healthy foods when I watch TV.		.772			
	BEH 4	I eat fruits.		.855			
	BEH 5	I eat vegetables.		.837			

Note. "α = Cronbach's Alpha AVE: Average Variance Extracted, CR: Composite Reliability; Negatively worded items were reverse-scored."

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Data Analysis

SPSS was used to conduct descriptive statistics. Reliability analysis and exploratory factor analysis (EFA) and AMOS was used to perform confirmatory factor analysis (CFA) and path analysis. The data process included two stages: Measurement and structural models (Byrne, 2016). Before carrying out the measurement model, the EFA (see Table 2) was conducted to identify the factors using principal component analysis (PCA). Firstly, items were tested whether they are appropriate to factor analysis. It was found that since Bartlett's test of sphericity was significant and Kaiser-Meyer-Olkin value (.902) was higher than .60 (Tabachnick et al., 2018), EFA is suitable for extracting salient factors. Finally, PCA revealed that total variance was explained with 79.12%, the eigenvalues were above 1.0 and factor loading of items in HBM and TPM were more than .50.

Table 2
Factor Loadings Obtained from Exploratory Factor Analysis

Constructs	Items	Factor component										
		1	2	3	4	5	6	7	8	9	10	11
Perceived Severity	PSV 1	.80										
	PSV 2	.78										
	PSV 3	.78										
Perceived Susceptibility	PS 1		.80									
	PS 2		.78									
Perceived Barriers	PBR 1			.81								
	PBR 2			.78								
Perceived Benefits	PB 1				.81							
	PB 2				.76							
	PB 3				.74							
	PB 4				.72							
Self-Efficacy	SE 1					.75						
	SE 2					.81						
	SE 3					.71						
	SE 4					.77						
Cues to Action	CA 1						.77					
	CA 2						.76					
	CA 3						.71					
Attitude	ATT 1							.72				
	ATT 2							.81				
	ATT 3							.79				
	ATT 4							.74				
	ATT 5							.71				
	ATT 6							.85				
	ATT 7							.81				
Subjective Norm	SN 1								.77			
	SN 2								.72			
	SN 3								.76			
Perceived Behavioral Control	PBC 1									.88		
	PBC 2									.79		
	PBC 3									.82		
	PBC 4									.81		

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Intention	INT 1										.81	
	INT 2										.82	
	INT 3										.79	
Behavior	BEH 1											.81
	BEH 2											.82
	BEH 3											.71
	BEH 4											.79
	BEH 5											.80

Note. PSV= Perceived Severity, PS= Perceived Susceptibility, PBR= Perceived Barriers, PB= Perceived Benefits, SE= Self-Efficacy, CA= Cues to Action, ATT= Attitude, SN= Subjective Norm, INT= Intention, BEH=Behavior

The measurement model consists of reliability including Cronbach Alpha (α) and Composite Reliability (CR) and validity including convergent and divergent validity (Bagozzi & Yi, 2012), while structural model tests the goodness of fit statistics of the proposed model (Anderson & Gerbing, 1988). The analysis of measurement model using maximum likelihood estimation method revealed acceptable goodness of fit indices (χ^2=416.15, *df*=145; *p*< .05; χ^2/df=2.87; *GFI*=.90 *TFI*=.92; *CFI*=.91; *RMSEA*=.07; *SRMR*= .06). In addition, since the value of factor loadings and Average Variance Extracted (AVE) were higher than .05, reliabilities of constructs, and CR were above than .70 (Bagozzi & Yi, 2012) and the square root of the AVE was bigger than correlation values (Carmines & Zeller, 1979), convergent (Table 1) and discriminant validity (Table 3) were established.

Table 3
Descriptive Values, Correlations and Discriminant Validity

	M	SD	PSV	PS	PBR	PB	SE	CA	ATT	SN	PBC	INT	BEH
PSV	4.29	.99	.71										
PS	4.19	.92	.67	.80									
PBR	4.08	1.01	-.60	-.67	.77								
PB	4.16	1.18	.43	.72	-.69	.75							
SE	4.57	1.02	.52	.71	-.65	.62	.73						
CA	4.49	.88	.39	.71	-.54	.66	.54	.72					
ATT	4.85	1.96	.60	.68	-.67	.69	.47	.65	.73				
SN	4.72	1.14	.67	.65	-.63	.68	.67	.54	.55	.75			
PBC	4.88	1.06	.38	.42	-.45	.55	.69	.35	.42	.35	.80		
INT	4.66	.94	.53	.74	-.54	.66	.36	.36	.47	.54	.42	.73	
BEH	4.59	1.12	.49	.69	-.47	.60	.31	.32	.41	.49	.35	.68	.82

Note. The bold values are indicator of square root of AVE for each variable. PSV= Perceived Severity, PS= Perceived Susceptibility, PBR= Perceived Barriers, PB= Perceived Benefits, SE= Self-Efficacy, CA= Cues to Action, ATT= Attitude, SN= Subjective Norm, INT= Intention, BEH=Behavior

Research Results

Structural Equation Modeling

Structural equation modeling (SEM) indicated the structured models of HBM, TPB and proposed model satisfactorily fit the data (See Table 4). The proposed model (χ^2/df=2.65) had a better fit than the TPB (χ^2/df=2.85) and HBM (χ^2/df=2.92). In addition, the proposed model had more predictive ability for intention and behavior (R^2int=.532; R^2beh=.483) than TPB (R^2int=.511; R^2beh=.419) and HBM (R^2int=.463; R^2beh=.354).

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Table 4
Goodness Fit Data for HBM, TPB and Proposed Model

Goodness Fit Statistics & R²	HBM	TPB	Proposed Model
χ^2	557.72	547.20	498.20
df	191	192	188
χ^2/df	2.92	2.85	2.65
CFI	.90	.92	.94
GFI	.91	.91	.93
TLI	.91	.93	.95
SRMR	.05	.04	.03
RMSEA	.05	.05	.04
R^2 (Adjusted)			
Intention	.46	.51	.53
Behavior	.35	.42	.48

Results of path analysis showed that, among HBM constructs, perceptions of susceptibility (β= .48), severity (β= .44), benefit (β= .42), cues to action (β= .31), and self-efficacy (β= .39) had a positive relationship with intention to eat healthy. However, the relationship between perception barriers and intention was negative (β= -.32). Therefore, Hypotheses 1-6 were supported (p<.05). The association among the TPB constructs demonstrated that attitude toward healthy eating (β= .35), subjective norm (β= .28) and PBC (β= .49) had a significant influence on intention. Finally, there was a significant relationship between healthy eating intention and behavior (β= .40). Hence, hypotheses 7, 8, 9 and 10 were all supported. In addition, the path between attitude toward healthy eating and perceptions of susceptibility (β= .38), severity (β= .36) and benefit (β= .47) was significant. These findings supported Hypotheses 11-13 (p<.05). With regards to total variance explained, it was revealed that 34% of variance in attitude was explained by perceived susceptibility, perceived severity, and perceived benefit. In addition, constructs of HBM and TPB explained 53% of the variance in healthy eating intention. Lastly, 48% of the variance in healthy eating behavior was explained by intention. A summary of the results is displayed in Table 5 and Figure 2.

Table 5
SEM Results of the Conceptual Proposed Model

Hypothesis	Pathway	Standardized estimate (β)	t-value	Hypothesis situation
H1	PS → INT	.48	10.689	Supported
H2	PSV → INT	.44	10.158	Supported
H3	PB → INT	.42	9.874	Supported
H4	CA → INT	.31	7.358	Supported
H5	PBR → INT	-.32	7.598	Supported
H6	SE → INT	.39	9.125	Supported
H7	ATT → INT	.35	8.025	Supported
H8	SN → INT	.29	6.899	Supported
H9	PBC → INT	.49	10.789	Supported
H10	INT → BEH	.40	9.598	Supported
H11	PS → ATT	.38	8.741	Supported
H12	PSV → ATT	.36	8.301	Supported
H13	PB → ATT	.47	10.489	Supported

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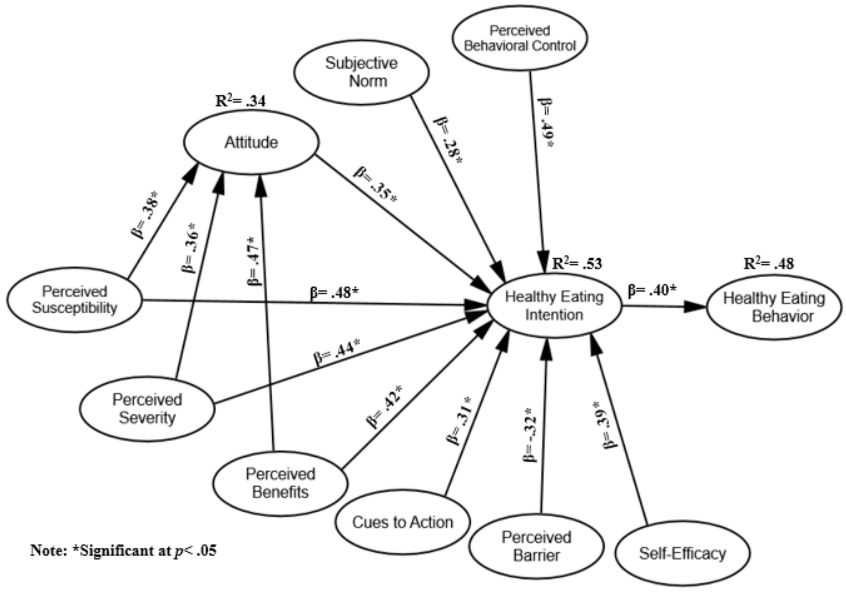
Figure 2
Result of the Structural Equation Modeling



Testing the Indirect Effects

The results of the indirect relationship between the constructs in the proposed model showed that perceived susceptibility (β= .29, p < .01), perceived severity (β= .26, p < .01), and perceived benefit (β= .24, p < .01) had significant indirect influence on healthy eating intention through attitude. In addition, healthy eating behaviors were indirectly influenced by both constructs of HBM (βPS=.23, p<.01; βPSV=.21, p<.01; βPB=.18, p<.05; βCA=.11, p<.05; βSE=.17, p<.05, βPBR= -.13, p<.05) and TPB (βATT=.15, p<.05; βSN=.10, p<.05; βPBC=.24, p<.01) via intention. More detail related to the indirect relationship is involved in Table 6.

Table 6
Indirect Relationships

Indirect effect of	On	
	Intention	Behavior
Perceived Susceptibility	.29*	.23*
Perceived Severity	.26*	.21*
Perceived Benefits	.24*	.18**
Cues to Action	-	.11**
Self-Efficacy	-	.10**
Perceived Barriers	-	-.13**
Attitude	-	.15**
Subjective Norm	-	.10**
PBC	-	.24*

Note. *Significant at .01, ** Significant at .05

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Discussion

In the current study, a comprehensive theoretical framework was prepared based on HBM and TPB to provide an understanding of science teachers' healthy eating intentions and behaviors. These two theories were combined into a model by considering the interrelation among their main constructs. The proposed model was supported by the data as a comprehensive model of science teachers' healthy eating intentions and behaviors, and this had important implications for demonstrating how pro-social and rational antecedents drive such a health-related decision. The results of the study revealed that the proposed model (R^2int=.53; R^2beh=.48) had better explanatory power to explain intention and behavior than TPB (R^2int=.51; R^2beh=.42) and HBM (R^2int=.46; R^2beh=.35). This caused to be an increase in intention and behavior (2 % and 6%, respectively) in variance accounted for by constructs of HBM over and above that accounted for by constructs of TPB. Moreover, 34% of attitude was explained by perceived susceptibility, perceived severity, and perceived benefit. Therefore, the findings showed that the conceptual model is wide-ranging, adequate, effective and functional in understanding science teachers' healthy eating intentions and behaviors. The comprehensive model can also be an important tool for a clear understanding of science teachers' complex decision formation regarding healthy eating in science, health, and nutrition education literature.

Regarding the relative criticality of used constructs in the model, the prominent importance of PBC was identified. Particularly, the non-volitional construct together with other constructs had a significant influence on healthy eating intentions and behaviors, and this construct was found to be the most effective when compared with other constructs in the proposed model. The finding is in line with the earlier study results that emphasized the importance of perceived ease or difficulty of performing the healthy eating behavior (e.g., Ateş, 2019; Bazillier et al., 2011; Brouwer & Mosack, 2015; Grønhøj et al., 2013). Moreover, the salient role of perceived barrier and self-efficacy variables, which were frequently associated with PBC and were emphasized to be significantly related to health-related behaviors in previous studies (e.g., Cook, 2018; Gerend & Shepherd 2012; Huang et al., 2020) was proven in this study. It implies that the perceived difficulties or hindrances related to the target behavior and the confidences in their ability to engage in the behaviors towards different barriers play an essential role on science teachers' healthy eating behavior. In addition, the main results demonstrated that perceived susceptibility, perceived severity, and perceived benefit and cues to action predicted healthy eating intentions. The findings implied that healthy eating intentions were explained by people's beliefs about the seriousness of the results of healthy eating behaviors, potential advantages of displaying healthy eating behaviors, and triggers of healthy eating behaviors including teacher, doctor, family, and friend. Such similar findings were obtained to be consistent with the results of other researchers (e.g., Kim et al., 2012; Orji et al., 2012). In addition, the current study has an original contribution to the literature since it explored the certain antecedent beliefs which were important in affecting science teachers' attitudes toward healthy eating. Examining antecedent beliefs is scarce in earlier study testing the HBM and TPB for health-related behavior context (e.g., Huang et al., 2020), and the use of antecedent beliefs has not been investigated in the context of healthy eating behavior and science education. Moreover, attitude successfully predicted healthy eating intentions. This indicates the importance of positive attitude towards healthy eating among science teachers during behavior. Therefore, a favorable attitude could be a good beginning to motivate science teachers' healthy eating behaviors. Last but not least, science teachers' intention to eat healthy was also determined by their subjective norm implying that behaving in accordance with a healthy eating became a social norm. Furthermore, receiving approvals of people who are important to science teachers in Turkey is very important for healthy eating. For example, in the school setting, since other teachers or school administrators are often considered important persons to teachers, science teachers are more likely to act according to their approval. This result also approves the importance of subjective norm in influencing healthy eating intentions in earlier studies (e.g., Ateş, 2019; Fila & Smith, 2006; Shimazaki et al., 2017).

Results of the testing of the indirect influence of constructs of study showed that attitude and healthy eating intention played an essential mediating role in the proposed framework. Among the constructs, perceived susceptibility, perceived severity, and perceived benefit had indirect impact on intention and behavior through attitude toward healthy eating. In addition, all variables of the HBM and TBP were indirectly related to healthy eating behaviors. The results were in line with those from earlier studies which is quite rare on health-related decisions, which merged the HBM and TBP (e.g., Huang et al., 2020).

The results have also some practical implications for education stakeholders, curriculum developers and science educators. The results can be reported that attitude towards healthy eating behaviors, subjective norm, perception of severity, susceptibility, barriers and benefits and beliefs of self-efficacy and cues to action were found to be

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significant antecedents in motivating science teachers' healthy eating intentions. Accordingly, it is essential for the ministry of national education, and provincial directorate of national education to design and launch influential nutrition-related promotional programs to increase the above-mentioned factors to achieve substantial social change towards a healthy eating lifestyle. For example, in-service health promotion training programs designed by school management and provincial directorate of national education for science teachers can play an important role in developing their beliefs, attitudes, intentions and behaviors. In the education of pre-service science teachers, who have a very important role in the education of future generations, more courses can be included in the curriculum they take at the university, aimed at gaining the awareness of healthy eating.

Limitations and Future Studies

Although the study made important contributions to the literature, it has several limitations and suggestions for future studies. First of all, the study is limited to several data collection tools, hypotheses and educated respondents using the convenience sampling method in several cities in Turkey. Therefore, as generation beyond the sample in the study is limited, this may be resulted in a demographic bias, may decrease external validity, and therefore give rise to sampling bias. Future researchers should extend their studies with more appropriate instruments and hypotheses using larger sample groups in different cultures. Individuals' eating beliefs and motivations may change according to the cultural characteristics, since individuals are likely to have particular beliefs and needs affected by cultural values (Seegebarth et al., 2016). In the study, the data collection tools relied on self-report measures rather than the actual behavior, thus the findings should be taken with caution, participants may not desire to express their true views due to the social desirability and ethical pressure to indicate their intentions to act toward the common good (Kiatkawsin & Han, 2017). Therefore, it is suggested to consider the results in the study with this understanding that future researchers can use other data sources such as supervisory ratings (Zhang et al., 2017). Finally, since the study focused on constructs of the HBM and TPB, some important constructs can be overlooked. For example, the constructs of the proposed model are based on expectancy-value framework developed in accordance with rational considerations. Therefore, the proposed model ignores non-rational motives in understanding healthy eating behaviors. Therefore, the validity and effectiveness of the theoretical framework can be questioned when explaining healthy eating behaviors. In future studies, more theories or models such as social cognitive theory, protection motivation theory, health action process approach and model of health literacy can be tested to examine the influence of different psychological constructs such as outcome expectancy, value of action, motivational and moral considerations on healthy eating intentions and behaviors which can provide more comprehensive understanding of the topic.

Conclusions and Implications

Decision-making process of individuals regarding healthy eating has not been investigated much in the extant literature. This study added several important elements to the existing nutrition, science and health education literature. Firstly, this study is probably the first attempt to determine antecedents of science teachers' healthy eating intentions and behaviors combining HBM and TPB in Turkish context. Secondly, the combined model determined that nine predictors had a significant impact on science teachers' healthy eating intentions which was a strong determinant of healthy eating behavior. Thirdly, attitude toward healthy eating derived from the TPB was successfully influenced by perceived susceptibility, perceived severity and perceived benefit, constructs of the HBM. Fourthly, attitude toward healthy eating, and intention to eat healthy as mediators were influential in building a framework explaining that science teachers make decisions that give importance to healthy eating. Considering the successful results of this study, the theoretical and practical importance of the proposed conceptual framework including high efficiency, comprehensiveness and applicability is remarkable.

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AN EVALUATION OF THE CREATIVE DRAMA METHOD USED IN THIRD- AND FOURTH- GRADE CLASSES ON ENVIRONMENTAL TOPICS BY TEACHING METHOD AND TEACHER EFFECT

Nilgün Bakkaloğlu,
Pınar Özdemir Şimşek

Abstract. *This study deals with the effects of applying drama method in the teaching of environmental issues in science courses on the achievement, retention of learning, student interest and attitudes of primary school students and also whether these effects are dependent on teachers. The study was designed on the basis of the Solomon Four-Group Design. The study is a two group pre- and post-test experiment in two parts, each part having an experimental and control group. The courses were delivered to both groups by the researcher in the first part and drama teacher in the second. The experimental groups received 144 hours of teaching for six weeks, during which a drama course outline was employed, while in the control groups the courses followed the course outlines covered in the curricula. The data were collected using the Environmental Achievement Test, Interest Scale towards the Environment and Attitude Scale towards Science. The findings suggest that the teachers had some effects on the methods, but the significant differences in scores were due to the drama method, which was found to improve the achievement of the third-grade students and the interest towards environment and attitudes towards science of both third- and fourth-grade students.*

Keywords: *environmental education, creative drama method, science education, teacher effect*

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Introduction

Environmental problems have increased in recent years, suggesting that information on the environment is incomplete (Erten, 2006; NEETF, 2005; Yılmaz, 2006) and human actions are not environmentally benign. Therefore, it is important to improve environmental information and activities. Thus, an environmental education program should be developed to teach people about the effects of their acts on the environment (WCED, 1987) and positively change these acts (Kıyıcı, 2009; Yıldırım, 2015). Environmental issues are a very important subject area for students because of their significant effect on their present and future lives. However, environmental education is considered only in science courses. Instead, it should be an independent part of educational programs (Chepesiuk, 2007) taught using active teaching methods, not through information transmission (Gautreau & Binns, 2012; Leeming, 1997).

Studies suggest that, in Turkey environmental education is not considered a priority field, that the curricula are not sufficient to improve either environmental sensitivity or environmental awareness, and that students' information about interest and sensitivity towards the environment are not at a desired level (Erten, 2006; Yılmaz, 2006). Alp et. al. (2006) argue that environmental issues are not much more emphasized in Turkish education programs than other subjects and that the environmental education offered is not action-oriented. However, it has been argued that environmental education should be in an applied form and should focus the students' immediate environment, suggesting that otherwise it would not be meaningful for students (Sobel, 1996, cited in Louv, 2010). Furthermore, the class hours devoted to environmental education should be extended and teachers should pay greater attention to environmental education.

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Given that environmental sensitivity begins to develop from the years 9-10, the period of primary education is very important for environmental education (Kıyıcı, 2009). However, primary school students are still at the age of play (Davis, 1998; Willson, 1996) and therefore instructional activities for them cannot be separated from games. In this period, playing games is one of the most important needs of children and they could acquire many significant skills through games. It is well known that, for effective teaching, relevant methods and techniques should be applied to encourage activity among students at the age of play (MEB, 2018) and that art activities improve students' achievement (Louv, 2010). When students actively participate in their courses, their knowledge becomes permanent and meaningful. Therefore, more student-centred activities should take place in the teaching process (MEB, 2018). It is important to organize learning environments in which students will actively learn environmental issues through doing and experiencing in primary school (Tilbury, 1994). Environmental education addresses students' cognitive, affective, and psychomotor learning areas (Erten, 2006). Creative drama is an effective method of improving cognitive, affective, and psychomotor skills in environmental education (Alrutz, 2004; Arieli, 2007; Bailey, 1994; David et al., 2013; Kaaland-Wells, 1994; McNaughton, 2004; Ødegaard, 2003; Vargas, 1995). When students learn environmental issues through drama, they may develop a connection between daily life and the topics of environmental education and their learning will be longer-lasting, being based on using their own observation and experience through games and improvisations. Such learning creates an interest in environmental issues in students and improves their achievement (Forgasz, 2013). It also improves their attitudes towards the environment. The creative drama method makes learning both enjoyable and concrete and therefore makes the topic much more interesting.

The creative drama method has been used in contemporary teaching at almost all levels of education and at every grade level with desirable results on student achievement, student interest, and attitudes in different courses and subject matters (Abed, 2016; Arieli, 2007; Bailey, 1994; David et al., 2013; Fleming, Merrel ve Tymms, 2004, Greenwood, 2001; Kaaland-Wells, 1994; McNaughton, 2004; Vargas, 1995). However, there is still a need to analyse it from different perspectives. İn particular, teacher effects are significant in various teaching methods and such effects should be determined for the creative drama method (Kaba & Özdemir, 2012; Özdemir & Çıkla, 2005). It has been demonstrated in some studies that the realization of the intended achievements in creative drama mostly depends on the attitude and character of drama teachers (Kaba & Özdemir, 2012; Özdemir & Çıkla, 2005). It is known that teachers' inadequacy in the drama method, their inability to plan the process, and their negative beliefs about the method adversely affect the implementation. Isenberg and Jalango stated that teachers have a strong impact on drama studies with children (cited in Köksal, 2012). Moreover, the creative drama method is highly influenced by teacher characteristics (Kaba & Özdemir, 2012; Özdemir & Çıkla, 2005). More specifically, its success is highly dependent on teachers' perspectives on the method, their desire to employ it, and their competency in using it. Teachers should have information about the drama methods and techniques. Most drama teachers have an insufficient knowledgebase (Adıgüzel, 2002). If the teachers do not have the necessary knowledge and skills for creative drama, the effects of the drama activities will not reach the desired level. Teachers should therefore improve their knowledge and skills in creative drama (Köksal, 2012), and the creative drama method should be employed by teachers who know it well. This study is original in that it included a sample of third-grade students and dealt with the teacher effect of the creative drama method.

Research Aim and Research Questions

Besides the methodology, based on the importance of teacher effect on experimental studies and use of a new discipline; creative drama as a methodology, the aim of this research is to reveal the effects of using the creative drama method in teaching environmental problems on the science achievement, attitudes towards science, environmental interest scores and their retention of primary school third and fourth grade students. Another important aim of the research is to reveal whether the practitioner has an effect on the results obtained after the experimental procedure. These aims were operationalized through the following research questions: 1) What is the effect of applying the creative drama method in teaching environmental issues on the achievement, science attitude, retention, and environmental interest scores of the third- and fourth-grade students in the experimental group? 2) Do the scores of the experimental group students differ according to whether the researcher or the teacher is in the classroom?"

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Research Methodology

General Background

In this study, an experimental method was used. The study was based on the Solomon Four-Group Research Design. The research consisted of a combination of two pre-test-post-test control groups. The model was developed to test the effect of the teachers implementing the drama method on the experimental process (Figure 2).

Figure 1
The Model Employed in the Study

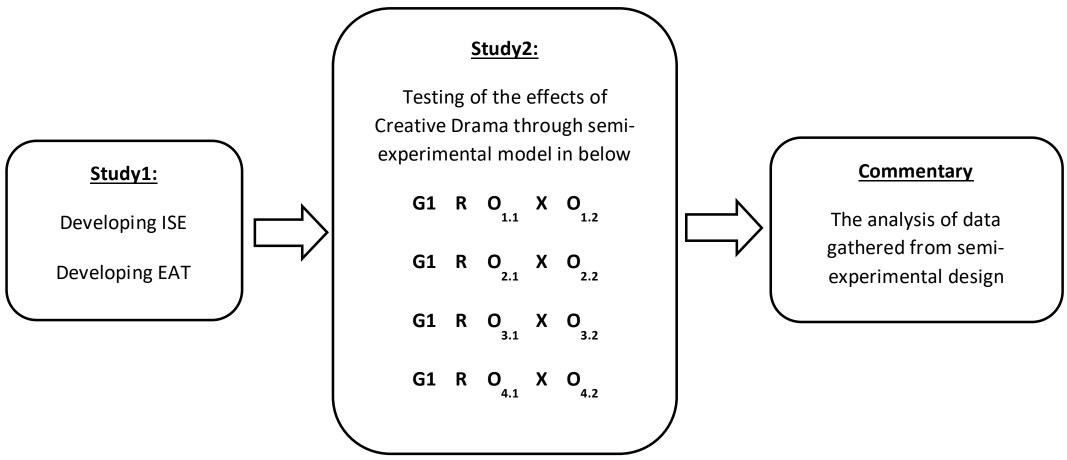
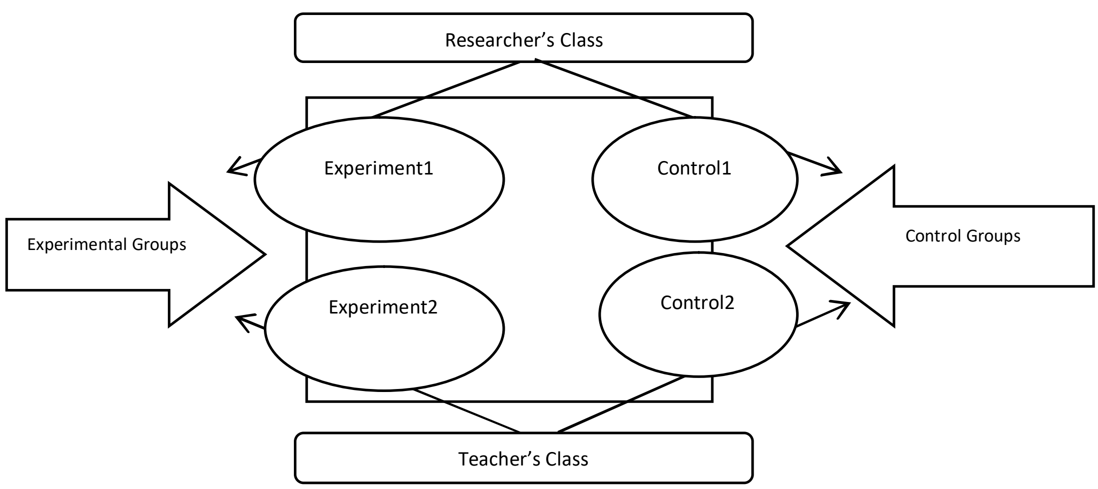


Figure 2
Groups Taught by the Researcher and Teacher



As can be seen in Figure 2, the courses for the Experimental and Control groups were delivered by the researcher-classroom teacher, and those for the Experiment2 and Control2 groups by a drama teacher. The courses were taught by different teachers to test the effect of the teachers on the experiment and the students, if any. The goal here was to test the effect of the method on the experimental process and the students without the influence the teacher makes. Therefore, the teacher effect was controlled. Thus, it can be said that the result in the experiment emerged independently from the teacher's influence. To clarify whether the differences in results were the effect

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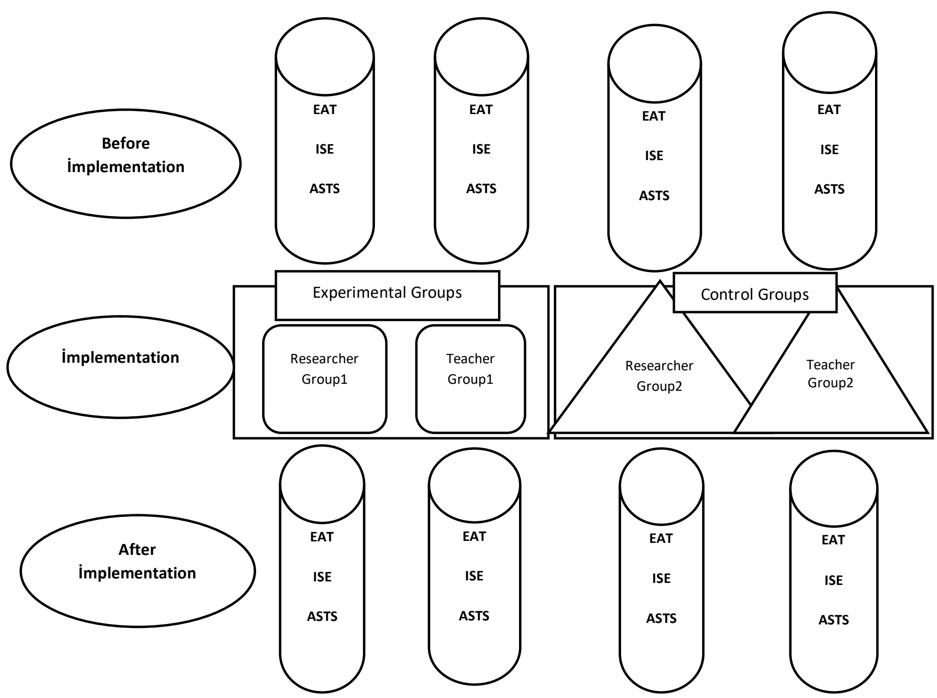
of the teacher, the method employed, or both the teacher and the method. Since one of the teachers who taught the courses was also the researcher, it was thought that bias of the independent variable might affect the research. It may also be that bias in the independent variable may affect the study because one of the teachers was also the researcher. Thus, the difference of the teacher could be clearly controlled. The difficulty of the model is that any study carried out with four groups simultaneously requires a significant amount of energy and effort from the researcher (Fraenkel & Wallen, 1996). Another difficulty specific to this research is that both teachers needed to be an expert in drama. Table 1 summarizes the experimental design of the study.

Table 1
Experimental Design of the Study

Group Label	Pre-test	Activity	Practitioner	Post-test	Retention Test
$Experiment_1$ 3E-4B	EAT,ISE,ASTS $O_{1.1}$	Drama Method	Researcher	EAT,ISE,ASTS $O_{1.2}$	EAT $O_{1.3}$
$Control_1$ 3I-4H	EAT,ISE,ASTS $O_{2.1}$	Non	Researcher	EAT,ISE,ASTS $O_{2.2}$	EAT $O_{2.3}$
$Experiment_2$ 3C-4E	EAT,ISE,ASTS $O_{3.1}$	Drama Method	Teacher	EAT,ISE,ASTS $O_{3.2}$	EAT $O_{3.3}$
$Control_2$ 3G-4G	EAT,ISE,ASTS $O_{4.1}$	Non	Teacher	EAT, SE,ASTS $O_{4.2}$	EAT $O_{4.3}$

Figure 3
The Order of the Data Collection Tools



The courses given to the $Experiment_1$ and $Experiment_2$ groups were delivered using the drama course outlines and those to Control1 and Control2 groups using the course outlines given in the education program. The administration of the data collection tools is given in Figure 3.

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Participants

The participants were third- and fourth-grade primary school students attending a public school in the Mamak District of Ankara during the 2015-2016 school year. The participants were selected through random sampling (Balcı, 2005). More specifically, 231 third- and fourth-grade students who did not take a drama course participated in the study. There were four third-grade (3E, 3C, 3G, and 3I) and four fourth-grade (4E, 4B, 4G, and 4H) branches. Given that the students were similar in terms of age and socio-economic status, there was no special process to match the students. The experiment and control groups were selected randomly. Therefore, in the study a semi-experimental design was employed. Table 2 shows the distribution of the participants.

Table 2
Distribution of the Participants

Groups	Grades	Female	Male	*N*	Total	Total
Experiment 1	3-E	14	9	23	43	89
	4-B	9	11	20		
Experiment 2	3-C	18	5	23	46	
	4-E	12	11	23		
Control 1	3-I	15	15	30	72	142
	4-H	28	14	42		
Control 2	3-G	19	14	33	70	
	4-G	20	17	37		
Total						231

The quantitative data of the study were collected through the administration of the following instruments: Environmental Achievement Test (EAT), Interest Scale towards the Environment (ISE), and Attitude Scale towards Science (ASTS; Geban et. al., 1994). All these instruments were employed as both pre- and post-test. In addition, the EAT was administered to all groups five weeks after the study as a retention test.

Instrument and Procedures

Environmental Achievement Test (EAT): The EAT has versions for third- and fourth- grade students. It was developed to measure the current knowledge and retention of students. It was used as pre-test, post-test, and retention test in the study. The items of the test were based on related studies and textbooks, and then revised. On the basis of expert feedback, the test was used in a pilot study with a sample of 489 third- and fourth-grade students. The mean difficulties for the third-grade and fourth-grade versions were found to be 0.64 and 0.54, respectively. Item discrimination was found to range between 0.16 and 0.68. In the interpretation of the discrimination of items, only those items with a discrimination greater than 0.30 and those with a discrimination of 0.20-0.29 were included in the test. The others were excluded (Atılgan et al., 2009). For the third-grade version, the KR-20 internal consistency coefficient was found to be 0.773. As a result, item 2 was excluded, resulting in a 20-item test. For the fourth-grade version, item 11 was excluded, yielding a KR-20 internal consistency of 0.827. It consisted of 24 items.

Interest Scale towards The Environment (ISE): The Interest Scale towards the Environment (ISE) was developed by the author. At the beginning of the development of the scale, a group of 40 students were asked to write essays on the environment which then were analysed using content analysis. Then the science curricula of the third- and fourth- grades and those gains on environment were reviewed. Next the related studies (Erdogan & Marcinkowski, 2015; Maskan et al., 2005) were reviewed before the draft was developed. To test its understandability and duration, a study was carried out on a sample of 50 students. On the basis of expert feedback and the results of the study, a second draft version with 50 items was constructed. A pilot study was carried out on a sample of 545 third- and fourth-grade students. Exploratory factor analysis was carried out to determine the factor structure and validity of the scale, revealing that it had a single factor. In the scale development process, the criterion that the factor load should be at least 0.45 was used (Büyüköztürk, 2012). The test includes 11 items on 5-point Likert scale. Table 4 gives the variance values, factor loads, and item-total correlations.

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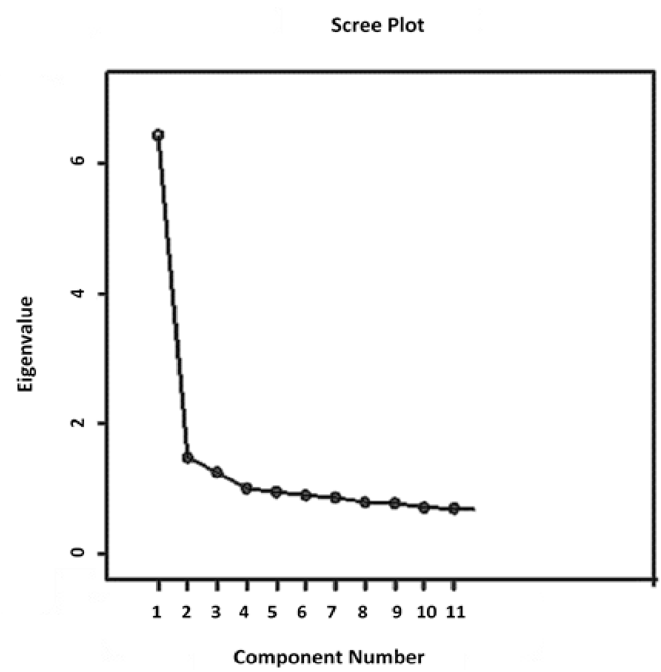
Table 3
Variance Accounted for According to Exploratory Factor Analysis

Factor	Eigenvalues				
	Total	Variance accounted %	Cumulative Variance %	Factor load	Item Total correlation
1	6.43	29.21	29.21	.505	.420
2	1.49	6.76	35.97	.528	.404
3	1.26	5.72	41.69	.505	.426
4	1.01	4.61	46.30	.553	.526
5	0.96	4.37	50.67	.548	.461
6	0.91	4.14	54.81	.483	.417
7	0.87	3.97	58.78	.539	.494
8	0.80	3.65	62.43	.559	.500
9	0.79	3.59	66.02	.555	.499
10	0.72	3.27	69.29	.511	.460
11	0.71	3.21	72.50	.491	.489

Kaiser-Meyer-Olkin sampling adequacy: .920
Chi-square value of the Bartlett's Test of Sphericity = 2860.930, *SD*=231, $p = .001$

The Kaiser-Meyer-Olkin statistic is .920; and a value greater than .50 indicates that the sample is adequate (Kalaycı, 2010). The Bartlett's Test of Sphericity was used to determine whether the data were appropriate for factor analysis. The results showed that the data were proper for the analysis ($p < .05$). It was also found that the factor loads varied between .483 and .559 and that the item-total correlations ranged between .404 and .526. The Cronbach's α for the scale was .877, indicating a high level of reliability. The eigenvalue for the single factor was 6.43, accounting for 29% of the variance. Figure 4 shows the eigenvalues.

Figure 4
Graph of Factor Eigenvalues



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Attitude Scale towards Science (ASTS): This scale, developed by Geban et al. (1994), analyses the student attitudes towards science courses. The scale has 15 items and its value of Cronbach's α was found to be .83 in this study. It was applied as a pre- and a post-test in this study.

Creative Drama Course Outlines: The author developed 14 drama course outlines. These outlines were used in the courses given to the experiment groups. The outlines were developed on the basis of student interests, the developmental characteristics of children, the structure of the method, teachers' guidebooks, annual lesson plans, and various textbooks (Davis & McGregor, 2011; Üstündağ, 2012). The plans were examined by five classroom teachers and three creative drama teachers at the school and modified on the basis of their feedback. The course outlines included three sections: preparation-warming, improvisation, and evaluation. During the first section, the students prepared for the course. In the improvisation section, the roles were distributed to the students prepared for their roles. In evaluation, the students briefly talked about the implementation. A sample course outline is given in the Annex 1.

Pre-İmplementation Activities: The researcher participated in drama teacher training courses before the study to learn about the method. The course plans were examined by five classroom teachers and three creative drama teachers at the school. The plan was employed in a course at the fourth-grade level. The experimental subjects received six hours of a pre-implementation course designed to test the experiments in terms of aims and duration. The findings from these courses were used to improve the course outlines. Before implementation, the researcher and teacher gave information about the creative drama method to the students in the experimental group. They were also informed about what they were expected to do during the implementation and activities.

Implementation: After receiving permission from the Ankara National Education Directorate and Governorship, the study was initiated during the spring semester of the 2015- 2016 school year. Although the study began for both groups simultaneously, the experimental section lasted longer. More specifically, the implementation for the experimental groups lasted six weeks, and a total of 36 hours, 6 per week, were devoted to the study. The total of course hours for the control group was 144. It was limited to 12 hours or four weeks, as covered in the science education program. The school's multi-purpose hall was used as a study area, which was redesigned to facilitate the drama activities. However, in some cases the creative drama method was employed in crowded classes and small areas. Therefore, in the first two sessions classroom rules to guide the student behaviours were identified and hung on the wall of the classroom for reference whenever necessary. In this way, all students were made active participants in the process and became more collaborative (Levey, 2005). At all stages, especially in the most important stage of creative drama, namely the improvisation phase, every student in the class was given a role. They were also made active participants of the drama activities.

Treatment Verification: The researcher observed both the experimental and control groups during implementation in order to monitor the degree of application of the experimental protocols. The observation form created by the researcher was used to ensure that the drama lesson plans were applied only in the experimental groups. The observation data showed that the drama method was not applied to in the control groups, nor was the traditional method employed in the experimental groups. In addition, the observation form was important for comparing the atmosphere in the classrooms. On the observation form, there were 30 items on a 4-point Likert scale: "good, intermediate, bad, not implemented". For the observation form the observation form used by Yılmaz (2007) in the PhD Thesis entitled Finding Anchoring Analogies to Help Student's Misconceptions in Physics was adopted. The Observation Form is given in the Annex 2.

Data Analysis

The quantitative data were statistically analysed with the significance level set at .05. The following statistical methods were applied in this study: SPSS 22 was used.

1. The Kolmogorov-Smirnov and Shapiro-Wilks normality tests were used to examine the distribution of the data obtained in the study and to test whether the data showed normal distributions.
2. Independent- samples t-tests and the Mann- Whitney U test were used for pairwise comparison of classes EAT, ISE, ASTS and ASTS Retention scores.
3. MANCOVA was used to compare the EAT post-test scores of the experimental and control groups.

Validity and Reliability of the Research: The factors that might affect the validity, reliability, and results of the research were all determined and controlled. The study group characteristics that might threaten the internal validity of the study were described in detail, and it was sought to control the different characteristics of the study

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groups as independent variables. The participants were randomly assigned to the groups. The matching of the groups in terms of socio-economic condition and other variables was made with maximum care. The data collection tools were administered in a safe and comfortable environment; each of the scales was administered on a different day; and the data analysis was carried out in a proper environment. The fact that both the researcher and a drama teacher taught the courses is important for determining any teacher effect observable in the research. The research model, study group, data collection tools, data analysis, and interpretation process were all explained in detail to establish the external validity of the study.

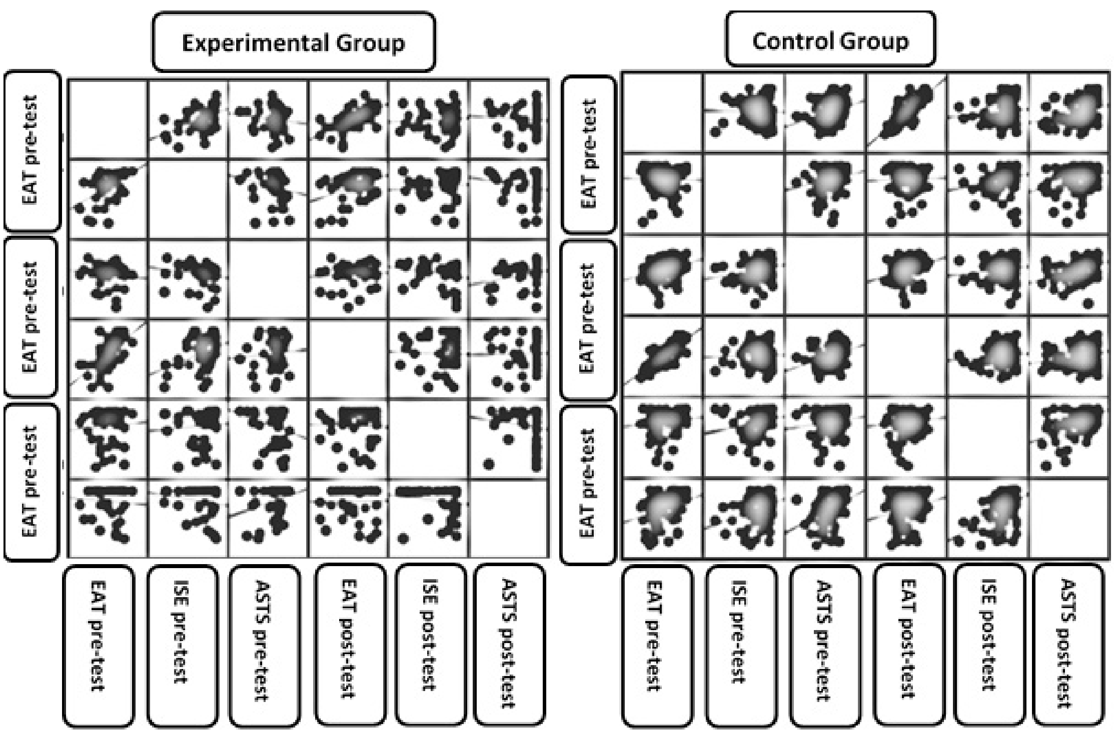
Research Results

Effects of the Method

The normality test was performed to test the assumption of univariate normality, and the skew values were examined. In order to analyse multivariate normality, scatter- plots were investigated. The relationships between the control variables and dependent variables were analysed using the Pearson correlation coefficient. In addition, the relationships among the dependent variables and those between the dependent variables and others were analysed using scatter-plots. To examine the equality of the regression lines, they were analysed by considering the significance of EAT pre-test scores on the "Test of Between Subjects" table.

Third-Grade Students: Before the MANCOVA analysis the normality of the distributions of the control variables (EAT, ISE, and ASTS pre-test) and dependent variables (EAT, ISE, and ASTS post-test) on the groups or independent variables was analysed. The Shapiro- Wilks and Kolmogorov-Smirnov tests were used to analyse the skewness and kurtosis values. The analysis showed that the scores were normally distributed. As stated earlier, multivariate normality was diagrammed as shown in Figure 5.

Figure 5
Distribution Chart of the Control and Dependent Variables for the Third- Grade Students



As can be seen in Figure 5, the control variables and dependent variables show a linear correlation. The distributions are expected to be elliptical, and the figures above seem to be nearly elliptical. When the Pearson

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correlation coefficient of the control and dependent variables of third-year students were examined to analyse the relationship between the common and dependent variables, it was found that all variables showed a significant correlation. In addition, ISE pre-test scores were found to have low correlations with the ASTS pre-test and EAT post-test scores. The ASTS pre-test scores had low correlations with EAT post-test scores, and similarly, EAT post-test scores had low correlations with ISE post-test scores ($r < .30$). The homogeneity of the variance-covariance matrices of the scores of the dependent variables was tested. The results of the Box's M test showed that the variance-covariance matrices were not homogeneous ($p < .05$). According to the results of Levene's test, conducted to test the equality of variances the variances of the EAT post-test and ISE post-test scores were found not to be equal ($p < .05$), while that of the ASTS post-test scores was found to be equal ($p > .05$). The assumption of the equality of the slopes of the regression lines was tested, and it was found that the common effects of the dependent variables by groups were significant ($p < .05$). In other words, the slopes of the regression lines are not equal. According to the results of the analysis, the descriptive statistics of the dependent variables are given in Table 4.

Table 4
Mean and Adjusted Average Values of Dependent Variables by Groups

	Group	Mean	Corrected mean	*N*
EAT post-test	Experimental group	12.02	12.26	45
	Control group	11.30	11.13	63
ISE post-test	Experimental group	104.67	105.13	45
	Control group	99.48	99.14	63
ASTS post-test	Experimental group	71.42	71.95	45
	Control group	65.95	65.58	63

Table 4 shows the EAT, ISE, and ASTS post-test score averages and corrected averages of 108 students in the experimental and control groups. The mean scores of the students in the experimental group were higher on all three tests. In terms of common effects, the differences in the post-test scores on the EAT [$F_{(4\text{-}103)} = 4.66$, $p < .05$], ISE [$F_{(4\text{-}103)} = 12.12$, $p < .05$], and ASTS [$F_{(4\text{-}103)} = 31.64$, $p < .05$] by group were significant. On the basis of the partial η^2 values, it is seen that the variance accounted for by the post-test scores of the EAT is 4%; by the ISE, 11%; and by the ASTS, 24%. The Wilks' Lambda values, which demonstrate the significance of the effects of common variables and group variables, are given in Table 5.

Table 5
Wilks' Lambda values on Common Variables and Group Variables

	Wilks' Lambda	*F*	*p*	η_p^2	Observed power
EAT pre-test	.71	13.83	.000	.29	1.00
ISE pre-test	.87	4.89	.003	.13	.90
ASTS pre-test	.69	15.31	.000	.31	1.00
Group	.74	11.90	.000	.26	1.00

As can be seen in Table 5, the pre-test scores of the EAT, ISE, and ASTS have basic effects on the group variables ($p < .01$). Partial η^2 values show that the total variance of the dependent variables accounted for by the EAT pre-test scores is 29%; by the ISE pre-test scores, 13%; and by the ASTS pre-test scores, 31%, while the group variable accounts for 26%. The observed power values for whether the null hypothesis is incorrectly rejected are .90 and higher, indicating that the null hypothesis was correctly rejected.

The significance of the difference between the averages was examined by group. It was found that the post-test scores on the EAT, ISE, and ASTS differ significantly by group ($p < .05$). The significance of the difference between the adjusted mean scores was found to be significant ($p < .05$). Accordingly, the EAT, ISE, and ASTS post-test mean

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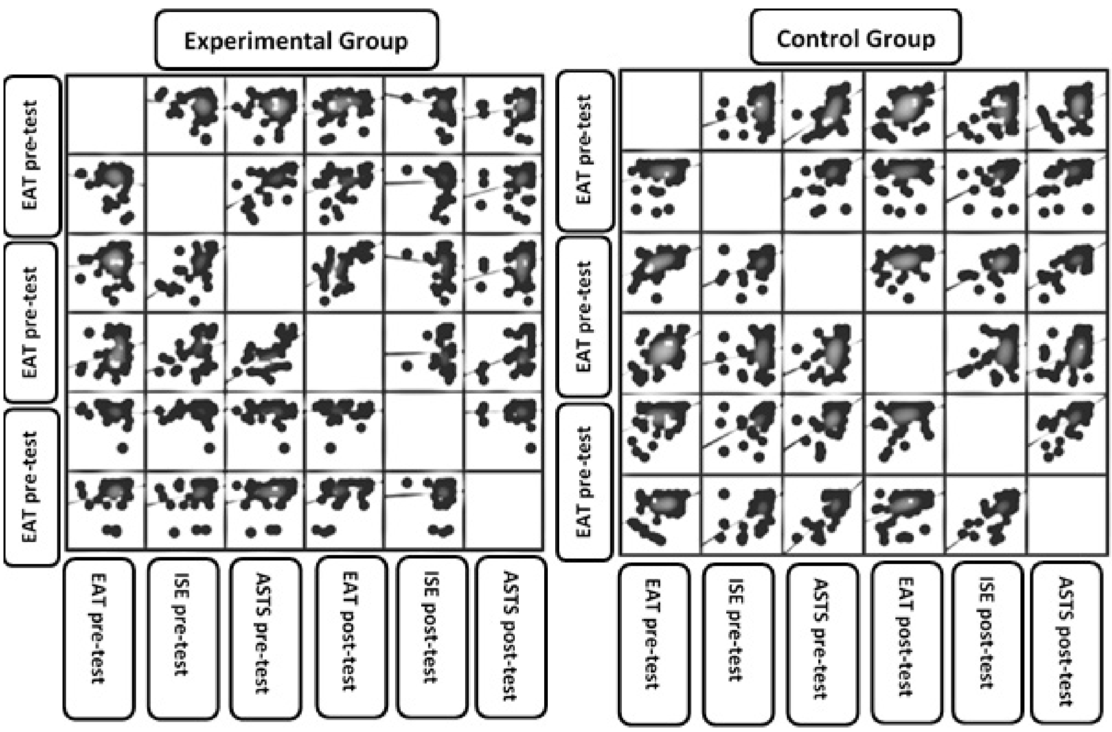
scores of the students in the experimental group were higher than those of the students in the control group. This shows that the experimental procedure is effective.

Fourth-grade Students: Before the MANCOVA analysis, the normality of the distribution of the control variables (EAT, ISE, and ASTS pre-test) and dependent variables (EAT, ISE, and ASTS post-test) on the groups or independent variables was analysed. The results of the normality tests (i.e., Shapiro-Wilks and Kolmogorov-Smirnov) indicated that the scores had a normal distribution without any significant deviation (Field, 2005; Kalaycı, 2010; Tabachnick & Fidel, 2001). The scatter plot drawings for multivariate normality analysis were developed. These figures are given in Figure 6.

Figure 6

Distribution Chart of the Control and Dependent Variables for the Fourth- Grade Students



As can be seen in Figure 6, the relationship between control variables and dependent variables is linear. The distributions are expected to be elliptical, and the analysis showed that the distributions are indeed close to the elliptical. The Pearson correlation coefficients for the control and dependent variables of the fourth- grade students were calculated to investigate the relationship between common and dependent variables, showing that the EAT pre-test scores have significant correlations with the ASTS pre-test, EAT post-test and ASTS post-test scores ($p < .05$). In addition, the ISE pre-test scores are significantly correlated with the ASTS pre-test, ISE post-test, and ASTS post-test scores ($p < .05$). Furthermore, the EAT post-test scores are significantly correlated with the ASTS post-test scores ($p < .05$). However, the EAT pre-test scores have no significant correlations with the ISE pre-test and post-test scores ($p > .05$). In addition, the ISE pre-test and post-test scores are not significantly correlated ($p > .05$). Furthermore, the EAT post-test scores have no significant correlation with the ISE post-test scores ($p > .05$).

The homogeneity of the variance-covariance matrices of scores related to dependent variables was tested. The covariance matrices are not homogeneous according to Box's M test ($p < .05$). According to the results of Levene's test, conducted to test the equivalence of variances, the variances of the EAT, ISE and ASTS post-test scores are not equal ($p < .05$). The assumption of the equality of the slopes of the regression lines was tested, showing that the common effects of the dependent variables were significant by group ($p < .05$). In other words, the slopes of the regression lines are not equal. The descriptive statistics of the dependent variables in the MANCOVA analysis are given in Table 6.

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Table 6
Mean and Adjusted Average Values of Dependent Variables by Group

	Group	Mean	Corrected mean	*N*
EAT pre-test	Experimental group	15.00	13.19	43
	Control group	12.68	13.67	79
ISE pre-test	Experimental group	104.81	104.01	43
	Control group	98.59	99.03	79
ASTS pre-test	Experimental group	71.53	69.75	43
	Control group	65.35	66.33	79

Table 6 shows the mean scores and corrected averages of the EAT, ISE, and ASTS post-test scores for 122 students in the experimental and control groups. Therefore, the EAT post-test scores do not vary significantly by group [$F_{(4\text{-}117)} = .36$, $p > .05$]. However, the post-test scores of the ISE [$F_{(4\text{-}103)} = 6.50$, $p < .05$] and ASTS [$F_{(4\text{-}103)} = 7.17$, $p < .05$] show significant variance by group. On the basis of the partial η^2 values, it can be stated that the post-test score of the EAT accounts for 0.3% of the variance; this figure is 5.3% for the ISE post-test and 5.8% for the ASTS post-test. As can be seen, the variance accounted for by the EAT post-test is very low. The Wilks' Lambda values, which test the significance of differences in common variables by group, are given in Table 7.

Table 7
Wilks' Lambda Values for Common Variables by Group

	Wilks' Lambda	*F*	*p*	η_p^2	Observed power
EAT pre-test	.65	20.26	.0001	.35	1.00
ISE pre-test	.93	3.01	.033	.07	.70
ASTS pre-test	.85	6.84	.000	.15	.97
Group	.92	3.29	.023	.08	.74

As can be seen in Table 7, the pre-test scores of the EAT, ISE, and ASTS show a main effect of group ($p < .05$). The partial η^2 values indicate that the total variance of the dependent variables accounted for is 35% for the EAT pre-test scores, 7% for the ISE pre-test scores, 15% for the ASTS pre-test scores, and 8% by group. The observed power values for whether the null hypothesis is incorrectly rejected were less than .90 for the ISE pre-test, but higher than .90 for the EAT pre-test and ASTS pre-test. Given that this value is .90 or greater, it indicates that the hypothesis of absence of effect is correctly rejected.

The significance of the difference between the mean scores was examined by group. It was found that the post-test scores of EAT did not significantly vary by group ($p > .05$). However, the post-test scores of the ISE and ASTS significantly differed based on groups ($p < .05$). A significant difference between the adjusted mean scores ($p < .05$) was found. Therefore, it can be argued that the ISE and ASTS post-test mean scores of the students in the experimental group were higher than the students' mean scores in the control group. Hence, this shows that the experimental procedure was effective.

The pre-test and post-test scores of the third- and fourth- grade students were compared. It was found that for the third- grade students the post-test scores of the EAT, ISE, and ASTS differ significantly in favour of the experimental group. For the fourth- grade students, the post-test scores of the ISE and ASTS differ significantly in favour of the experimental group. It may be stated that the use of the drama method in teaching environmental topics improved the academic achievement of the third- grade students and the student interest and attitudes of both third- and fourth- grade students.

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The Teacher Effect

The groups were then compared to answer the following research question: Do the scores of the experimental group students differ according to whether the researcher or the teacher is in the classroom? The teacher effect was analysed on the basis of the results of the EAT, ISE, and ASTS and on the results of the ASTS as a retention test by a comparison of the Experiment$_1$ and Experiment$_2$ groups whose lessons the researcher and the teacher led, respectively, for a significant in results. The t-test was used to analyse the significance of the differences of the gains in EAT scores of the Experiment$_1$ and Experiment$_2$ groups of third- grade students, while the U test was used to analyse the significance of the differences of the gains in EAT scores of the Experiment$_1$ and Experiment$_2$ groups of fourth- grade students. The results of the t-test and U test are given in Table 8.

Table 8
T-Test and U-Test Results for the Gain in EAT Scores of Third- and Fourth- Grade Students by Group (Experiment$_1$ and Experiment$_2$)

	Group	N	$\bar{X}$	SD	df	t	p
Third grade	Experiment$_1$	23	.65	2.29	44	−1.17	.248
	Experiment$_2$	23	1.52	2.78			
	Group	**N**	**Mean Rank**		**Rank Sum**	**U**	**p**
Fourth grade	Experiment$_1$	20	13.43		268.50	58.50	.0001
	Experiment$_2$	23	29.46		677.50		

As Table 8 shows, the gains in the scores of the third- grade students in the Experiment$_1$ and Experiment$_2$ groups did not differ significantly [$t_{(44)} = -1.17, p > .05$]. In other words, they obtained similar gains in scores. The experimental process similarly influenced the students of both groups. However, the gains in scores of the fourth-grade students in the Experiment$_1$ and Experiment$_2$ groups significantly differed ($U = 58.50, p < .05$). More specifically, on the basis of the mean ranks, the achievement of the students in Experiment$_2$ was higher. These findings indicate that there was no teacher effect for the third- grade students for either the experimental or the control group. However, this effect was observed for fourth- grade students. The reason for this finding can be stated as follows: Both teachers are proficient in drama, and the drama teacher is more experienced than the researcher in the drama method. The t-test was used to analyse the significance of the differences in gains in the EAT scores of the Control$_1$ and Control$_2$ groups of third- grade students. The U test was used to analyse the significance of the differences of the gains in EAT scores of Control$_1$ and Control$_2$ groups for the fourth- grade students. The results of the t-test and U test are given in Table 9.

Table 9
T-Test and U-Test Results of Gains in EAT Scores of Third- and Fourth- Grade Students by Group (Control$_1$ and Control$_2$)

	Group	N	$\bar{X}$	SD	df	t	p
Third grade	Control$_1$	30	.17	2.98	61	1.28	.205
	Control$_2$	33	−.88	3.45			
	Group	**N**	**Mean Rank**		**Rank Sum**	**U**	**p**
Fourth grade	Control$_1$	42	45.57		1914.00	543.00	.019
	Control$_2$	37	33.68		1246.00		

Table 9 indicates that the EAT gain scores of the control groups (Control$_1$ and Control$_2$) do not vary significantly by group [$t_{(61)} = 1.28, p > .05$] among the third- grade students. More specifically, those in Control$_1$ had similar gains in EAT scores as those in Control$_2$. However, among the fourth- grade students, the EAT gain scores of the control

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subjects (Control$_1$ and Control$_2$) differ significantly by group (U = 543.00, p < .05). The mean ranks show that the academic achievement of the fourth- grade students in Control$_1$ was higher than that in the other control group. These findings indicate that there was no teacher effect in the third- grade students regardless of the group. However, there was a teacher effect for the fourth- grade control groups. The reason for that can be the fact that both teachers had a competency in delivering the courses using the traditional teaching method. The Mann- Whitney U test was used to analyse the significance of the differences in the gains in ISE scores of the Experiment$_1$ and Experiment$_2$ groups of third- grade students. The U test was used to analyse the significance of the differences of the ISE gain scores of Experiment$_1$ and Experiment$_2$ groups of fourth- grade students. The results of the U test are given in Table 10.

Table 10

U-Test Results of the Gains in ISE Scores of Third- and Fourth- Grade Students by Groups (Experiment$_1$ and Experiment$_2$)

	Group	*N*	Mean rank	Mean sum	*U*	*p*
Third grade	Experiment$_1$	22	17.68	389.00	136.00	.008
	Experiment$_2$	23	28.09	646.00		
Fourth grade	Experiment$_1$	20	28.08	561.50	108.50	.003
	Experiment$_2$	23	16.72	384.50		

As can be seen in Table 10, the gains in ISE scores of third- grade students (Experiment$_1$ and Experiment$_2$) showed significant differences by group (U = 136.00, p < .05). The mean rank suggests that the interest of the students in Experiment$_2$ is much higher. The gains in ISE scores of fourth- grade students (Experiment$_1$ and Experiment$_2$) also showed significant differences by group (U = 108.50, p < .05). The mean rank suggests that the interest of the students in Experiment$_1$ is much higher. Therefore, it can be argued that there is a teacher effect for both experimental groups of third- and fourth- grade students. T-tests were used to analyse the significance of the difference in the gains in the ISE scores of the Control$_1$ and Control$_2$ groups of the third- and fourth- grade students. The results of the t-tests are given in Table 11.

Table 11

Results of T-Test of the Gains in ISE Scores of Third- and Fourth- Grade Students by Group (Control$_1$ and Control$_2$)

	Group	*N*	$\overline{X}$	*SD*	*df*	*t*	*p*
Third grade	Control$_1$	30	1.73	17.67	35.26	.52	.607
	Control$_2$	33	−.30	6.11			
Fourth grade	Control$_1$	42	.05	17.50	56.87	−.53	.585
	Control$_2$	37	1.68	7.45			

As can be seen in Table 11, the gains in ISE scores of the third- grade control subjects significantly differed by group (Control$_1$ and Control$_2$) [$t_{(61)}$ = .52, p >.05]. Both groups showed much the same gains in ISE scores. The gains in ISE scores of the fourth- grade control subjects also did not differ significantly by group (Control$_1$ and Control$_2$) [$t_{(56.87)}$ = –.53, p >.05]. More specifically, the fourth- grade students in the Control$_1$ had higher gains in scores than those in Control$_2$. In terms of the control group, there was no significant difference between the third- grade and fourth- grade students. A t-test was used to analyse the significance of the differences in the gains in ASTS scores of the Experiment$_1$ and Experiment$_2$ groups of third- and fourth- grade students. The results of the t-tests are given in Table 12.

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Table 12

Results of T-Test of the Gains in ASTS Scores of Third- and Fourth- Grade Students by Group (Experiment₁ and Experiment₂)

	Group	N	$\bar{X}$	SD	df	t	p
Third grade	Experiment_1	23	7.39	5.40	44	−.43	.670
	Experiment_2	23	8.39	9.80			
Fourth grade	Experiment_1	20	7.40	5.17	41	5.10	.001
	Experiment_2	23	−.13	4.51			

Table 12 indicates that the gains in ASTS scores did not significantly differ for the experimental groups (Experiment_1 and Experiment_2) of the third- grade [$t_{(44)} = -.43$, $p > .05$], suggesting that the experimental process had similar effects on both experiment groups. The gains in ASTS scores did, however, significantly differ for the experimental groups (Experiment_1 and Experiment_2) of the fourth grade [$t_{(41)} = 5.10$, $p < .05$]. More specifically, the students in Experiment_1 had much higher gains in scores on the ASTS than did students in Experiment_2, suggesting that the experimental process had much more positive effects on Experiment_1. The findings indicate that the effect of teacher was not found in the experimental groups at the third- grade level, but the teacher effect was observed at the fourth- grade level. A t-test was used to analyse the significance of the difference in the gains in ASTS scores of the Control_1 and Control_2 groups of third- grade students. For the fourth- grade students, the Whitney-Mann U test was employed. The results of the t-test and U test are given in Table 13.

Table 13

Results of T-Test and U tests of the Gains in ASTS Scores of Third- and Fourth- Grade Students by Group (Control₁ and Control₂)

	Group	N	$\bar{X}$	SD	df	t	p
Third grade	Control_1	30	.73	6.46	61	−.02	.988
	Control_2	33	.76	6.14			
	Group	**N**	**Mean Rank**		**Rank Sum**	**U**	**p**
Fourth grade	Control_1	42	36.58		1536.50	633.50	.158
	Control_2	37	43.88		1623.50		

As can be seen in Table 13, the gains in ASTS scores did not significantly differ for the control groups (Control_1 and Control_2) of the third- grade [$t_{(61)} = -.02$, $p > .05$]. The gains in ASTS scores of the third- grade control subjects are similar. Moreover, the gains in ASTS scores did not significantly differ for the control groups (Control_1 and Control_2) of the fourth grade ($U = 633.50$, $p > .05$). The gains in ASTS scores of the fourth- grade control subjects are similar. There is no teacher effect for the control groups of either third- or fourth- grade. The U test was used to analyse the significance of the difference in the EAT retention scores of the Experiment_1 and Experiment_2 groups of third- grade students. For the fourth- grade students, t-test was employed. The results of the U test and t-test are given in Table 14.

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Table 14
Results of T-Test and U Test on the EAT Retention Scores of Third- and Fourth- Grade Students by Group (Experiment$_1$ and Experiment$_2$)

	Group	*N*	Mean Rank		Rank Sum	*U*	*p*
Third grade	Experiment$_1$	23	23.41		538.50	262.50	.965
	Experiment$_2$	23	23.59		542.50		
	Group	***N***	$\bar{X}$	***SD***	***df***	***t***	***p***
Fourth grade	Experiment$_1$	20	13.65	5.26	41	−.02	.981
	Experiment$_2$	23	13.70	7.15			

Table 14 shows that the EAT retention scores did not significantly differ for the experimental groups (Experiment$_1$ and Experiment$_2$) of the third- grade (U = 262.50, p > .05). In other words, the EAT retention scores of the third- grade control subjects are similar. The EAT retention scores do not significantly differ for the experimental groups (Experiment$_1$ and Experiment$_2$) of the fourth grade [$t_{(41)} = -.02, p > .05$] either. Therefore, it can be stated that the experimental process equally affected the experimental groups. The U test was used to analyse the significance of the difference in the EAT retention scores of the Control$_1$ and Control$_2$ groups of the third- grade students. For the fourth- grade students, a t-test was employed. The results of U test and t-test are given in Table 15.

Table 15
Results of T-Test and U Test on the EAT Retention Scores of Third- and Fourth-Grade Students by Group (Control$_1$ and Control$_2$)

	Group	*N*	Mean Rank		Rank Sum	*U*	*p*
Third grade	Control$_1$	30	30.33		910.00	445.00	.489
	Control$_2$	33	33.52		1106.00		
	Group	***N***	$\bar{X}$	***SD***	***df***	***t***	***p***
Fourth grade	Control$_1$	42	9.00	6.03	68.41	−2.25	.028
	Control$_2$	37	12.51	7.62			

As can be seen in Table 15, the EAT retention scores do not significantly differ for the control groups (Control$_1$ and Control$_2$) of the third grade (U = 445.00, p > .05). Students' being in Control$_1$ versus Control$_2$ did not have a significant effect on their EAT retention scores. The EAT retention scores significantly differed for the control groups (Control$_1$ and Control$_2$) of the fourth grade [$t_{(68.41)} = -2.25, p < .05$] such that the EAT retention scores of the students in Control$_2$ were much higher than those of the students in Control$_1$. It can be stated that there was a teacher effect for the Control$_2$ group.

Discussion

Research suggests that drama method has various effects on student achievement, interest and attitudes in different courses and subject matters (Abed, 2016; Arieli, 2007; Bailey, 1994; David et al., 2013; Fleming, Merrel ve Tymms, 2004, Greenwood, 2001; Kaaland-Wells, 1994; McNaughton, 2004; Vargas, 1995). The drama method is highly influenced by the teacher who practices the method. The research model is designed to test whether the teacher had an impact on the experiment. It is important to investigate the effect of teachers especially in methods such as drama where achieving the intended objectives depends on teacher characteristics and it has been suggested that should be analysed (Kaba & Özdemir, 2012; Özdemir & Çıkla, 2005). For this purpose, with this study the effect of the drama method and the different teachers who employed the method on the students were investigated. To analyse the teacher effect, a comparison was made on the basis of the data gathered from the EAT, ISE, ASTS and EAT as a

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retention test. There were two experimental and two control groups in the study. In order to test the teacher effect, the experimental groups (Experiment$_1$ and Experiment$_2$) were compared, and the control groups (Control$_1$ and Control$_2$) were compared. The goal here was to test the effect of the teachers on the experimental process and the students.

The experimental and control groups were compared in terms of the student achievement scores. The findings suggest that there was no teacher effect for the third-grade students in improving achievement [$t_{(44)} = -1.17$, $p > .05$]. However, for the experimental groups of the fourth grade, there was a positive effect of the drama teacher [$U = 58.50$, $p < .05$], while for the control groups there was a positive effect of the researcher [$U = 543.00$, $p < .05$]. However, the fact that the same teachers did not make any difference on the experimental and control groups of either grade level shows that there was no teacher effect on the experimental process. In other words, the teachers made a difference in the experimental groups but not in the control groups, which shows that the teacher is competent in the methods but not influential on the experimental process. In order to have a real influence on the method, a teacher effect should have been observed in both groups.

The experimental and control groups were compared in terms of the students' interest scores in relation to the environment. The scores of the experimental groups on the ISE were higher than the control groups' scores. This method increased students' interest in the environment. In addition to the effect of the method, teacher influence was also observed in the increasing interest of the students. The findings suggest that, for the third-grade students, the increase in their interest was significantly related to the drama teacher [$U = 136.00$, $p < .05$], while for the fourth grade it was related to the researcher [$U = 108.50$, $p < .05$]. The effects of the drama teachers who taught the third-grade students involved increased interest in the environment. However, for the fourth-grade students, the effect came from the researcher, not from the drama teacher, which may be a result of the fact that at this grade level examinations and an exam-centred atmosphere were much more dominant. However, this effect of the teachers in the teachers was not observed in the control groups. Therefore, the existence of a complete teacher effect cannot be confirmed, as there was no significant difference between the scores of Control1 and Control2 groups.

The data analysis showed that the experimental groups had higher attitude scores than the control groups. It can be argued that when the drama method is employed in science courses, students' attitudes towards science are improved. In order to analyse the potential teacher effect, the Experiment1 and Experiment2 groups were compared with each other, as were the Control1 and Control2 groups. When the experimental and control groups were compared to see whether the attitude scores of the students were affected by the teachers, and no such effect was found for the experimental groups of the third grade [$t(44) = -.43$, $p > .05$]. However, for the fourth grade, a teacher effect was observed for Experiment1, which was taught by the researcher [$t(41) = 5.10$, $p < .05$]. There was no such effect for the control groups of the third grade [$t(61) = -.02$, $p > .05$] or the fourth grade [$U = 633.50$, $p > .05$]. It was also found that there was no teacher effect on the significant differences observed in the science attitude scores of the third-grade students. However, the same effect was not observed for the control groups. Therefore, it can be stated that there was no genuine teacher effect on the experimental process; rather, the teacher effect influenced the research through the method employed. This result, which was also observed in student achievement, shows that both teachers had the same effect on the experiment. The drama method was influential in increasing student attitudes, but a teacher effect was not observed. However, for the fourth-grade students, the science attitude scores of the class taught by the researcher were higher than for the other experimental group, which may indicate a teacher effect. The students knew the researcher as a teacher at the school. Therefore, they might have considered the activities much more seriously and thus shown much more interest and participation in the activities.

The experimental and control groups were compared among themselves to determine whether there was a teacher effect on the retention of environmental information. The results showed that both the third-grade experimental subjects [$U = 262.50$, $p > .05$] and the fourth-grade experimental subjects [$t_{(41)} = -.02$, $p > .05$] did not significantly differ. There is a meaningful difference between the control groups of the fourth grade in favour of the Control$_2$ group, in which the drama teacher taught the classes [$t_{(68.41)} = -2.25$, $p < .05$]. Therefore, it can be said that a teacher effect was found in the delivery of the traditional lesson plans at the fourth-grade level. However, it is not possible to talk about the effect of the teacher on the experimental environment, since there was no such difference in the experimental group where the drama teacher taught the classes. It can be said that the teacher factor made a difference in the students' retention scores.

In terms of the teacher effect, it can be stated that there is no teacher effect by method in the third and fourth grade. The researcher was influential in employing the drama method to increase the science achievement scores and science attitude scores of fourth- grade students. The drama teacher seems to play a significant role in increasing the retention scores of fourth- grade students over the traditional method of application. For the third- grade

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students, the creative drama method and creative drama teacher were effective in increasing their scores on interest in the environment.

The success of the drama method includes the teacher's approach to the method, teacher willingness and competency to employing the method. If teachers have the adequate information and skills for drama method, the effects of the drama activities will be so great. Negative attitudes and beliefs about the method, inadequacy of planning and using the method may adversely affect drama applications. McNaughton (2004) concluded that the students learned much new knowledge through the creative drama method and had fun at the same time. McNaughton (2004) found that the students defined creative drama as an educational activity that teaches them while entertaining them. David et al. (2013) concluded that the creative drama method facilitates student participation and makes them interested in the topic. Levey (2005) states that as a teacher who used it throughout the curriculum, he found the creative drama method particularly useful in environmental education. He further states the advantages of the method in learning environments as follows:

> "The use of creative drama in environmental education can make a huge difference in learning environmental issues. When students dramatize a topic, they begin to discover it from different perspectives and to develop relationships with it in a creative way. In doing this, students not only provide profound learning and retention in knowledge, but also gain a deep insight into themselves, other people, and even other creatures. Drama empowers students to expand their world experiences by empathizing with their surroundings to protect the environment (p.35)."

Conclusions and Implications

In short, it can be said that there are many factors affecting the success of the drama method such as an exam-oriented education system, student-teacher relationships, the socio-economic environment, and family demands. In this research, the effect of the teacher on the success of the method was studied. In general, the method had a positive effect on the students' attitudes towards science, their attitudes towards the science course, and their knowledge. Whether one of the teachers had an impact on this positive effect was also examined. It was found that the teacher was more effective in the methods but had no effect on the experimental procedure as a whole. More specifically, a teacher effect on the method was observed for the third-grade students, but a researcher effect was found for the fourth grade. However, the effects of the method cannot be neglected.

The achievement of the third-grade students participating in the study who were taught science education through the creative drama method for the first time was improved, and this positive effect was not a result of the teacher effect. The creative drama method was effective for students' achievement, interest, and attitudes in both experimental groups (Experiment$_1$ and Experiment$_2$). Given that the third-grade students were being taught science education for the first time, they had no expectations, which had positive effects on their results.

The findings of the study indicate that the achievements, interest towards the environment, and attitudes towards the science course of the third-grade students who received the course through the creative drama method were higher than for the control group students who were taught using the traditional method. This situation shows us that the drama method, which is one of the cornerstones of constructivist theory, should be used at all levels of education, starting from pre-school education.

Recommendations for Practitioners and Future Researchers

Discussions of environmental issues cover some environmental problems that seem to make students pessimistic. Therefore, environmental education should be taught to younger students using such methods as creative drama, which can positively affect the attitudes of students towards environment. Environmental issues should be taught using those methods that will enable the student to be active in daily life starting from the students' immediate surroundings and cultivating students' love of plants and animals. As environmental issues can be covered in almost any course, it is suggested that these issues be given in relation to all topics. Given that the success of the drama method depends on the teacher's success, teachers should participate in in-service training activities and other workshops organized to improve their knowledge and skills regarding the drama method. The drama method should be frequently included in the activities in textbooks and the recommended activities in teachers' guidebooks. Thus, teachers can become more interested in the subject. Increasing the number of hours devoted to teaching environmental issues will allow teachers to devote time to the methods that require more time to apply, such as creative drama. If the drama

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method is to be implemented for the first time in a group, the first few sessions should be planned to introduce the method. Having a hall or class specifically devoted to creative drama in schools will make the implementation easier and more practical. Classes with fewer students should be chosen for the implementation of the method, as creative drama practices will be difficult in crowded classes.

The results of the implementation of environmental education among younger students can be investigated and compared with the results of previous studies of samples of students from different age groups. The teaching methods and environmental attitudes of the teachers in primary schools regarding environmental issues can be investigated.

Limitations of the Study

This research has some limitations: This study, with 2015-2016 academic year; with a public primary school where the application will be carried out, with the 3rd and 4th year students who took creative drama method; with the environmental objectives and creative drama method in the 3rd and 4th grade curriculum; with pre-test, post-test, pre-interest, post-interest, pre-attitude, post-attitude and retention test scores was limited.

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Declaration of Interest

Authors declare no competing interest.

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A Sample Creative Drama Course Outline

Plan Label: Blue Lake	
Course: Science **Method:** Creative drama	**Place:** Multi-purpose hall
Topic/Concepts: School and environment, environmental cleaning, environmental pollution, environmental protection and beautification	**Techniques:** Role playing, improvisation, group pantomime, dull image.
	Students: 3rd. and 4th grade students
3rd Grade/Classes: 3E-3C **Unit:** Journey to the World of Living Beings/Living Beings and Life **Topic:** Me and My Environment **Date:**28/04/2016 **Duration:**40+40+40 mins	**4th Grade/Classes:** 4B-4E **Unit:** Microscopic Creatures and Our Environment/Living Beings and Life **Topic:** Human and Environmental Relations **Date:**29/04/2016 **Duration:**40+40+40 mins

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Learning Objectives	
3rd Grade: 1. Students recognize the environment in which they live and take an active role in the cleaning. 2. Students understand the importance of the natural environment for living things and take measures to protect.	**4th Grade:** 1. Students keep their surroundings clean to avoid environmental pollution. 2. Students discusses how environmental pollution can be prevented. 3. Students design a project to protect and beautify the environment.
Creative drama objectives: 1. Students respect the performance of their friends in the improvisation. 2. They could work with others. 3. They can work in a small group. 4. Students can evaluate others' work. 5. Students can take part in whole class improvisation. 6. Students can communicate with their peers. 7. Students can design improvisation according to a given topic.	
Materials: 1. Pictures showing clean days of the lake. Cardboard papers for each group 2. Written sentences on small slips of paper on air and water pollution. Pictures of air and water pollution. 3. CD player; for the 4th activity, Jazz Ensemble, The Taking of Pelham. 4. For the group pantomime, Taraf De Haidouks & Kocani Orkestar, -A la turk is used.	
Preparation: The impact of a clean or dirty immediate environment on human health and development is emphasized. It is also emphasized that a clean and green environment makes people happy. The teacher sounds out the opinions of the students on how dirty air and dirty water adversely affect health.	

Preparation/Warm-up

1ST ACTIVITY: Game of Air-Soil-Water: Children stand in a circle. When the teacher says "air," they act as if they are flying; when s/he says "water," they act as if they are swimming; and when s/he says "soil," they act as if they are digging something.

2ND ACTIVITY: Types of pollution: Children stand in a circle. Each student is given a label of a type of pollution. One student is chosen to be "it" and stands in the middle of the circle while trying to find a place in the circle during the game. Students are reminded not to forget the names they are given. When the game starts, one of the pollution types is called out. Those whose labels are called try to change their places in the circle. If "it" wants all of the children to change their places, "it" says "pollution basket" and tries to take the place of one of the children in the circle. If he can take someone's place he is no longer "it," but remains "it" otherwise. The game continues in this fashion.

3RD ACTIVITY: Mid-Evaluation: They talk about the answers to the following questions: How is air polluted? How is water polluted? What pollutes the air and water? How is the soil polluted? What should we do to avoid contamination of our environment?

4TH ACTIVITY: Find the Sentence—Find Your Pair: The students stand in a circle. Two copies of the sentences are prepared and written on small pieces of papers. These sentences are about either the reasons for air pollution or the ways to avoid air pollution. Then each of these pieces of paper is attached to one student. The students are asked to find the other student with the same sentence as theirs. The pairs stand where they are. Once the pairs of children are formed everybody reads their sentences one by one. The papers of the students having the second sentences are turned down and worn by the students. This time some of the students write the reasons for air pollution and the others the ways to avoid air pollution. Problems are matched with the right solutions.

5TH ACTIVITY: Outdoor Activity: During the previous drama activity, there was a survey questionnaire, "Let's Decorate the Newspaper Building with Flowers." There you were asked to state your favourite outdoor activities. Do you remember? What were these activities? Which activities were voted most highly in the survey questionnaire?

Where do you do during these outdoor activities? Are there any places where you can have a picnic and ride a bike near your home? A picture of the "Blue Lake" is shown to the students, and the teacher may tell them that they all know the Blue Lake. Then the following question is asked: What do people usually do at the Blue Bake? Students list the activities that can be performed at the Blue Lake. Playing ball, skipping rope, fishing, picnic with your family, etc. What else can be done at the Blue Lake? Let's think about it. The activities are then listed on a large cardboard paper.

Role Play/İmprovisations

6TH ACTIVITY: Still Image—I am at the Blue lake: Students are told to draw an activity that they would like to perform at the Blue Lake. They animate this activity through still image techniques. Each student animates the activity he / she wants to do. Some of the students are asked to tell what they want to do. Some students want to fly a kite, some to ride a boat.

• Some of them drew fishing, some having a picnic, some cycling, some traveling, some playing ball, some cooking kebabs. Some of them were visiting the place with their grandfather.

7TH ACTIVITY: Group Pantomime: Students are told to form a group by observing each other. Then the students in pairs or individually begin to animate the still images.

8TH ACTIVITY: Estimation: An estimation task is performed with the rest of the class. The teacher determines the four different activities that are performed by the students and points out four students who perform these activities well; the others are then asked to sit down. The four students are told to stay on the stage and continue their movements. The class is asked to think about which outdoor activities are being performed by these students. For instance, the groups attempted to portray "Look, there is an old man fishing here; who wants to go there?" In this way the other students are also taken to the stage.

• Most of the groups had more spontaneous reunions. For example, the cyclists were tired and stood next to the fishermen, and the kids playing ball were the children of the picnickers, etc.… The groups were formed in this way and the class was divided into groups of four.

9TH ACTIVITY: A Day at the Blue Lake: How do these four groups spend a day at the clean and orderly Blue Lake? The students are asked to think about it and animate part of it. Then, the students who had roles as picnickers, cyclists, kite-flyers, and fishermen animated how they spent a day at the Blue Lake.

While making the improvisation, relations began to develop among the still images in the sixth activity. All groups performed the improvisation successfully. The teacher wandered among the groups to see whether the students needed help. It was observed that the students were very harmonious and experienced because they had the Blue Lake experience during the improvisation.

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Evaluation

10TH ACTIVITY: Slogan Writing: Students produce slogans describing the effects of fresh air and abundant oxygen on human life. The slogans are turned into banners, and then the slogans with the most votes will be displayed in the school. Some of these slogans are;
"Clean your environment for protecting our planet"
"Clean air means healthy people"
"Cleanliness is happiness"
Assignment: Children paint pictures of the potential activities that may be performed at the Blue Lake.

Attachment 2

Observation Form

Dear Researcher/Practitioner
You involved in the courses of environmental education to the third and fourth grade students. Course outlines used for the experiment groups for which a creative drama method was conducted are given in attachment. Please carefully examine these outlines. Please answer the items below considering that a creative drama approach was used for the experiment groups, and it was not used for the control groups. Your answers should be expressed through one of four options, namely "good", "average", "not good" and "N/A". Put a sign on ( ) which is at the right side to indicate your answer, like (X). If you are asked to give the number of the activity, please give it on the proper box.

No:	Observation Questions	Good	Average	Bad	N/A
1	Did the group make a circle?				
2	Was there a mental preparation?				
3	Was there a physical preparation?				
4	Was the duration of the preparatory work sufficient? For a course duration of 40+40+40, were there preparations for 30 minutes?				
5	Were the warm-up activities made related to the objectives?				
6	Were improvisations performed?				
7	Were the activities made related to one another?				
8	Was the preparation made before the improvisation?				
9	Were the improvisation activities carried out in each lesson related to the objective of the related lesson?				
10	Were dramatic situations in the animations given clear?				
11	Was a dramatic situation used for each objective?				
12	Were the roles in improvisation clear?				
13	Were the purpose, status of and motivation for roles clear?				
14	Were the drama techniques used in the improvisation stage?				
15	Was the duration of the improvisation proper?				
16	Were the components of the dramatic fiction complied with?				
17	Were time and space clearly stated for the improvisations?				
18	Did the teacher play any role in improvisations that did not create conflict situations?				
19	Were the instructions given by the teacher clear and explicit?				
20	Was the intra-group communication sufficient?				
21	Was the duration of the improvisation work sufficient? For a course duration of 40+40+40, were there improvisations for 60 minutes?				
22	Was the role-playing technique used?				
23	Did students stand up during the course?				
24	Did the students sit on the ground from time to time during the course?				
25	Was the space used in a seated order?				
26	Was music used during the course?				

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No:	Observation Questions	Good	Average	Bad	N/A
27	Did students occasionally stand up during the course?				
28	Was the course delivered at the multi-purpose hall?				
29	Was the school yard used during the course?				
30	Were drama course outlines used?				
31	How do you rate the implementation of the daily plan by the teacher? Please choose the statement “the course was delivered exactly as stated in the daily plan” if you have positive views and choose the statement “the course was not delivered as stated in the daily plan” if you have negative views.				
32	Were the body of the students used as a material?				
33	Were there mid-term evaluations?				
34	Was there any evaluation at the end of the course?				
35	Did they play games?				
36	Did the teacher use direct instruction method?				
37	Did the students sit in a row?				
38	Were the students active during the course?				
39	Did the students interact with one another?				
40	Did the students freely walk around the space?				
41	Did the students use all parts of the space?				
42	Did the students move with music?				
43	Was any classroom used for the course?				
44	Were the products of the children developed in the course exhibited?				
45	Was the evaluation associated with achievements?				
46	Was the teacher used a textbook or printed material?				
47	Was any self-evaluation used?				
48	Was any peer evaluation used?				
49	Was any group evaluation used?				
50	Did the students play games from time to time during the course?				
51	Was the teacher warm and friendly?				
52	Was the teacher effective in involving students in activities?				
The points you want to add:					
Positive points:					
Negative points:					
Other:					

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THE EFFECT OF USING COMPUTER SIMULATIONS ON GRADE 11 LEARNERS' PERFORMANCE IN PLANTS BIODIVERSITY IN SOUTH AFRICA

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Abstract. *Teachers use different pedagogies to improve learners' performance. The study explored the effect of Computer Simulations (CS) on Grade 11 learners' performance when taught Plants Biodiversity. A Solomon Four-Group design was used to cater for internal and external validity. Sixty-six learners were assigned to two Control Groups (CG) taught using CS and 66 learners to two Experimental Groups (EG) taught using Talk and Chalk Method (TCM). The pre-test was administered to EG1 and CG1, while post-tests were administered to all four groups. Focus Group Discussion Interviews (FGDI) were conducted with 12 learners: six from EG and six from CG. Quantitative data were analyzed using a T-test, Analysis of Variance (ANOVA), while qualitative data were analyzed using thematic analysis. The results show that EG outperformed CG (T-test; ANOVA; p < .05). Boys' and girls' performance in EG did not differ significantly, suggesting that CS favour both gender to perform well. CS positively influenced EG learners' attitudes towards Biodiversity topic, but not CG. Thus, CS is an effective tool for enhancing learners' performance.*
Keywords: *computer simulations, Solomon Four-Group Design, learners' performance, Talk and Chalk Method (TCM)*

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Introduction

Improving learners' performance is a goal in teaching science subjects. Science teachers have diverse knowledge to teach different topics (Shulman, 1986). The teachers' knowledge to teach different topics is Pedagogical Content Knowledge (PCK) (Deidre, 2015; Shulman, 1986). PCK is distinct knowledge exclusive to teachers, distinguishing them from the subject content specialists (Shulman, 1986). Although researchers in teacher education have ignored PCK, Hill, Ball and Schilling (2008) report that the PCK teachers use can improve teaching and learning. Educational research shows that teachers' creativity in teaching affects students' learning (Kleickmann et al., 2013). Teachers direct special attention toward science topics: Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) (Sickel & Friedrichsen, 2017). Both types of knowledge affect teachers' instructional practices and student learning (Baumert et al., 2010; Hill et al., 2008). Shulman (1986) states that PCK is a cognitive construct representing an idea embedded in the teachers' beliefs. It is more than teaching content knowledge to learners since learning is not absorbing information for reproduction in the exams.

PCK is the fusion of content with methods of teaching (1986, 1987). This knowledge is not the same for all teachers, but it is explicit knowledge within a teacher's idiosyncratic practice. Thus, teachers can choose different teaching tools to assist them to enhance learning. According to Lowther et al. (2012) projectors, televisions, and computer laboratories are forms of technology to enhance learning. Using computers in teaching science is popular in the developed world and is slowly picking momentum in the developing world. Technology stimulates learning and more so, learners can manipulate objects using different devices (Kirkley & Kirkley, 2005). Also, teachers employ technology in numerous ways to address learners' needs (Koh et al., 2018). One approach is to use computers, which motivate learners. Also, teachers use Computer Simulations (CS) for teaching and for updating their content knowledge.

CS engage learners in understanding artificial as well as natural systems (Ramat & Preux, 2003). During simulations, students are the test subjects. CS contribute to the 'learners-play-to-learn' process where learners create

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knowledge through playing (Mavhunga & Kibirige, 2018), increases learners' interest (Yildirim & Sensoy, 2018) and enhances learners' knowledge retention (Popil & Dillard-Thompson, 2015). CS improve learning outcomes in the science classroom (Akpan, 2001) and are essential in research and investigations (Samsonau, 2018). Hannel and Cuevas (2018) reviewed teachers' use of CS and found that they assist learners in time management because less time was devoted to setting up apparatus. Besides, in EG learners changed variables to allow stating and testing hypotheses. In this context, a learner becomes active and improves in formulating questions, hypothesizing, collecting data, and revising theories. Interactive CS provide learners with a sense of ownership and thus increase content understanding as well as content retention (Ramos et al., 2016). Simulations allow learners to reproduce and envisage actual world processes that would take a long time or perilous processes in a high school laboratory context (Akpan, 2001).

Limniou et al. (2007) contend that replacing some laboratory lessons with cooperative pre-laboratories simulation increases learners' knowledge. Similarly, Dalgarno et al. (2009) used a 3-dimensional Virtual Laboratory (VL) and a Real Laboratory (RL) to acquaint learners with the long- term structure of laboratory apparatus. They concluded VL was effective for familiarisation with laboratory background. However, several studies opine simulations should not substitute physical laboratories (Limniou et al., 2009; Sypsas & Kalles, 2018). CS motivate learners to interact with real-life issues. Using CS, the teachers can regulate parameters to achieve the best learning outcomes (Hertel & Millis, 2002). Learners engage with simulations to alter parameters, and practice solving specific tasks. Thus, CS can be incorporated into learning to discover hypothetical situations. Learners can compare the information from CS with textbooks and notes from lectures to solve problems in a realistic mode to minimise learning difficulties (Samsonau, 2018).

Research Problem

Teachers use Pedagogical Content Knowledge (PCK) for specific topics and different contexts. This knowledge defines them as teachers. Sanders, Borko, and Lockard (1993) assert that experienced teachers have affluent PCK, while Chan and Yung (2018) indicate teachers' previous experiences may promote or hinder their new PCK development. Studies confirm teachers seldom use technology in addition to their PCK as Technological Pedagogical Content Knowledge (TPACK) to improve learning (Mavhunga et al., 2016). Teachers spend a long time talking in class and ask low order questions (Carlsen, 1993). Some teachers cannot identify learners' misconceptions (Hashweh, 1987) and consequently choose incongruous strategies to teach content. One strategy to improve learners' performance is to use CS. The effect of using CS on learners' performance has not been well studied, particularly in developing countries, where learners-to-computer ratio varies. For example, in Zambia, the learners to computer ratios were as high as 143:1 (Chaamwe, 2017; Sossa et al., 2015) and 17:1 in South Africa (Kibirige & Hodi, 2019). It should be noted that in South Africa as a developing country, learners are challenged in two aspects: 1) lack of access to the use a computer, learners cannot afford to own one (Habibi et al., 2018), and 2) learners have limited time to practice on the computer because they typically access the computer during school hours (Tarman & Chigisheva, 2017). Some content cannot be taught using hands-on activities in the classroom because of its abstract nature. In such instances, CS can be viewed in the classroom to minimize misconceptions on a specific topic. After all, misconceptions are context and topic-specific, making this study unique because, to the best of our knowledge, no studies used CS to teach a Plant Biodiversity topic in a rural school context in South Africa. This is a knowledge gap this study aimed to fill. Thus, the study investigated the effect of CS on learners' performance in Plant Diversity compared to the learners taught using (TCM).

Research Focus

The research focuses on the effect of CS, which engage learners in active participation more than the Talk and Chalk Method. The research contributes to literature from developing countries on learners' experiences of using CS to improve their understanding of science. CS assist learners to improve their attitudes and interests, and cognitive achievements in science (Tüysüz, 2010; Yildirim & Sensoy, 2018). Considering the vast majority of teachers using TCM in schools, which results in learners' poor conceptualisation and poor attainment in sciences, CS would change the paradigm and actively engage learners, especially during the COVID-19 era where face-to-face interaction is minimal. Thus, the findings from this study can benefit Life Science teachers, learners, curriculum, and material designers in chemistry to incorporate CS in the teaching of Life Sciences.

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Research Aim and Research Questions

Due to the scarcity of computers in schools in South Africa, many learners are assigned to one computer to access during their free time. The effect of using CS to improve learners' performance in Life Sciences in developing countries with limited computers is not well studied. Thus, the purpose of the study was to explore the effect of CS on Grade eleven learners' performance in a Plant Biodiversity topic. The study was to answer one question: What is the effect in learners' performance of teaching Grade 11 learners Plant Biodiversity using CS? The study addressed three hypotheses: 1) Pre-test learners' scores vary in EG and CG; 2) EG learners taught using CS perform better than CG learners taught using TCM; 3) There is no statistically significant difference in learners' performance between boys and girls in EG.

Research Methodology

General Background

The researchers used Solomon Four-Group Design (Cambell & Stanly, 1963) because of its robustness. It deals with internal validity, where one considers alternative causes, and external validity, where the results can apply to the entire population (Kirikkaya & Başgül, 2019). The design assists in 1) identifying the cause and effect of CS intervention. 2) The researcher can determine whether the administration of a pretest affected the dependent variable (Abaniel., 2021). Thus, this study differs from earlier quasi-experimental designs (Tlala et al., 2014), which did not cater for these two threats and hence results were not conclusive of the cause and the effect regarding the use of Predict-Observe-Explain (POE). The current design addressed the effect of Computer Simulations using a Biodiversity topic in rural South African schools during 2018. The research design is represented in Table 1.

Table 1
A Solomon Four-Group Design ($EG_{1;}$ CG_{1} pretested and $EG_{1;}$ $CG_{1;}$ $EG_{2;}$ CG_{2} post-tested)

Randomized Group	Pre-tested	Intervention	Post-tested
EG_1	Yes	Yes	Yes
CG_1	Yes	No	Yes
EG_2	-	Yes	Yes
CG_2	-	No	Yes

The target population was 200 Grade 11 Life science learners aged between 15 and 17 years with an average age of 16 years were purposively selected (Creswell, 2013) from four schools based on the availability of computers. The Raosoft Software sample calculator provided a sample of 132 learners, with a 6.95% margin of error at a Confidence Interval (CI) of 95%. This implies the sample was a representation of the population and therefore suitable for the study. 132 Grade 11 learners were randomly assigned to four groups: two groups with 33 per group as EG and two groups with 33 per group as CG. The researchers considered 33 learners per group adequate (Mugenda & Mugenda, 1999).

Instruments and Procedures

Pre- and post-tests and Focus Group Discussion Interviews (FGDI) were used to collect data.

The tests were checked for face validity by two lecturers and piloted to 20 learners from one school with a similar environment, which was not part of the study. For reliability, a Cronbach Alpha coefficient of .85 was obtained, which is acceptable because it is above .7 cut-off line (Muijs & Reynolds, 2011). The interview schedule questions were checked for face validity by two lecturers, and their recommendations were addressed before data collection.

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EG_1 and CG_1 were pre-tested, EG_2 and CG_2 were not pre-tested (Table 1), and the post-test was administered to all the four groups EG_1, EG_2, CG_1 and CG_2. Pre-post-test learners' scores were the independent variables. EG_2 learners were taught using CS to influence outcomes to assist researchers in assessing the impact of the treatment. Learners were taught during the usual school periods to avoid school curriculum disruption. The researcher accessed simulations from Physics Education Technology (PhET) online. Although the name appears as physics, the simulations include other subjects like Biology, Chemistry and Earth sciences. The topic was the main groupings of living organisms and their diagnostic features such as bryophytes, pteridophytes, gymnosperms and angiosperms. Although the regular class teachers were present during the teaching, they did not participate in the teaching. The researchers led the class in discussions and in answering questions regarding the simulations.

Four steps were followed during the lessons: 1) general introduction of the content - learners wrote their predictions on what Kingdom or Division the organism belong; 2) screening of Computer Simulations - learners observed; 3) reflections on the simulations - learners wrote explanations and discussed within the class; 4) wrapping up the lesson- the teacher clarified a few misconceptions and highlighted main ideas of the lesson. After an introduction, learners wrote their predictions following teachers' guides. During simulations they observed and identified different plants and classified them into their Divisions. For example, Bryophytes, learners predicted if the plant according to the structure was vascular or non-vascular; Pteridophytes - Spores but no seeds, Spermatophytes- Seed Plants, and Gymnosperms - naked seeds. The above content was in line with the Grade 11 curriculum. The study lasted for five weeks, where one week was used for acclimatization. Due to the shortage of computers in the schools, the learners-to-computer ratio was limited to four or five learners per computer and learners accessed computers at their opportune time after classes. Focus Group Discussion Interviews (FGDI) with 12 individuals (6 per group) were employed to collect the views on learners' attitudes before and after teaching. Each interview lasted approximately 30 minutes and was audio recorded. Four sessions were held, and the interviews ended when there was no extra information gained from the discussions.

Data Analysis

Quantitative data were analysed using means, standard deviations, T-test, and Analysis of Variance (ANOVA). Levene Test for Equality of Variances was applied to the pre-test scores to determine if the two groups (EG and CG) were equal. T-test was used on pre-test to detect equality of the two groups, and pre- and post-tests mean differences between EG and CG, and the gender differences in performances in EG. A 2 x 2 ANOVA test on four post-test scores (EG_1, CG_1, EG_2 and CG_2) was used to determine differences between the CG and EG. Finally, qualitative data were analyzed thematically using six steps of Braun and Clake (2006): reading line by line through the transcripts to be conversant with the texts, creating tentative codes, looking for themes, revising the themes, defining themes, and finally writing the themes.

Ethical Issues

The Education Department granted permission to carry out the study. All learners consented to participate, and their parents signed consent forms. During data collection, anonymity and confidentiality of participants were ensured throughout the entire study. To minimize learners' discrimination from a worthwhile teaching method, the other two classes taught without CS were given extra classes after the five weeks of intervention to experience the CS approach

Research Results

The results show that EG taught using CS performed better than CG, which was taught without CS. Levene Test for Equality of Variances $F = 1.64$, $p > .05$) showed no significant differences between the pre-test scores of EG and CG. The statistics related to equal variances were assumed, and hence the use of the t-test.

The results of pre-tested EG_1 and CG_1 using an independent T-test are presented in Figure 1 a-b.

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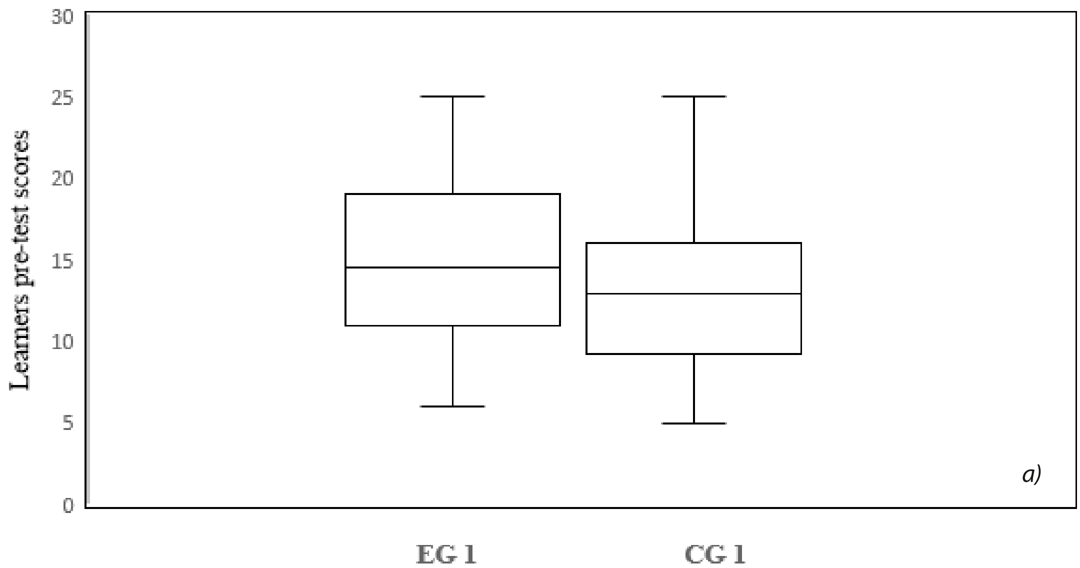
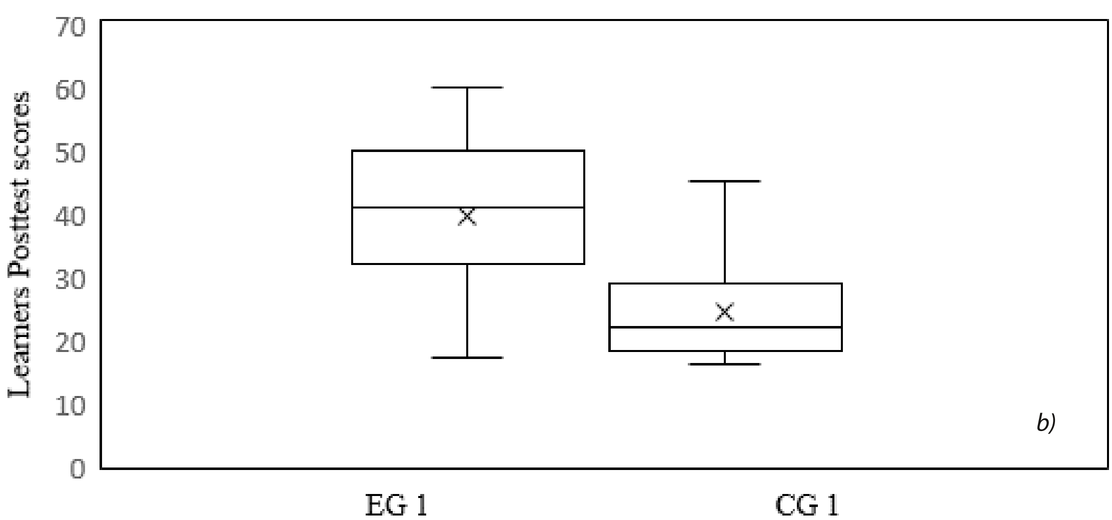
Figure 1 a-b

a) T-test results for pre-test for EG_1 and CG_1 groups before intervention.



b) T-test results for post-test for both EG_1 and CG_1 groups after intervention.



In Figure 1 a) pre-test results for CG (M = 12.94, SD = 4.90) and EG (M = 14.07, SD = 3.78) showed no significant differences T-test, $t(64) = 1.14$, $p > .05$). Thus, the learners had a similar understanding of science concepts before the intervention. Therefore, we reject Hypothesis one, which states that learners' scores vary in the pre-test.

After teaching for four weeks, the post-test results of EG_1 and CG_1 performances were compared using a T-test. Figure 1 b) shows results of the post-test scores for both EG_1 (M = 38.53, SD = 11.19) and CG_1 (M = 22.32, SD = 6.87) differed significantly after intervention T-tests, $t(64) = 7.19$; $p < .05$). Also, Cohen d results for EG_1 and CG_1 show a huge effect size of 2.02 for the EG_1 group compared to 1.6 for the CG_1. Effect size between the EG_1 and CG_1 .42 suggesting EG_1 performed better than the CG_1. Therefore, Hypothesis two, stating learners' performance does not vary in EG_1 and the CG_1 after intervention is rejected.

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Figure 2
T-test Results for Post-test for Males and Females in EG after Intervention

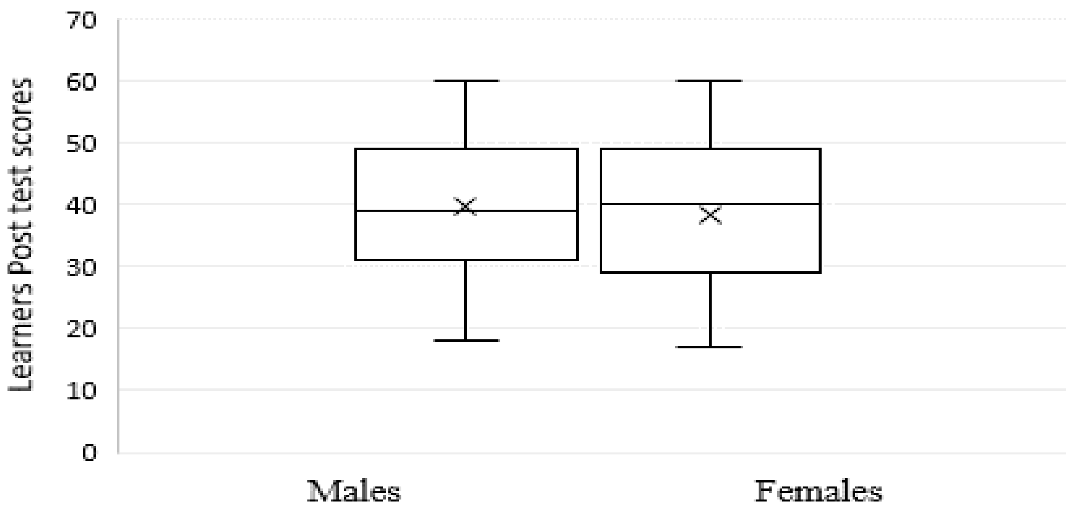

Figure 2 shows mean scores were ($M = 39.63$, $SD = 11.52$) for males and ($M = 38.67$, $SD = 12.08$) for females. No statistically significant differences were found among the two groups using a *T*-test, $t\,(64) = (.39)$; $p > .05$. Therefore, hypothesis three stating scores vary between boys and girls in EG after intervention is rejected.

ANOVA results of the treatment are represented below in Table 3.

Table 3
ANOVA Representing the Main Effect Test between EG and CG

Solomon Four Group	Type III SS	*df*	*MS*	*F*	*p*
Treatment versus No treatment	7592.86	3	2559.55	25.80	.01
Pre-tested versus Not Pre-test	86.11	1	124581.97	1255.71	.01
Treatment versus pretest	7.21	1	86.11	.87	.35
Error	7686.18	1	7592.86	76.53	.01
Total	144378.00	127	99.21	.07	.79
Corrected Total	20278.58	131			

In Table 3, the significance level (*p*-value) corresponding to treatment*pretest is .35, which is more than the .05, suggesting there is no interaction effect. The *p*-values corresponding to the Pre-tested versus Not Pre-tested and Treatment versus Not treatment are less than $p = .05$. Thus, there is a main effect between CG_1 and EG_1, and between pretested and not Pre-tested groups. Also, between groups variance is not greater than within groups variance because the $F = .87$ value is small.

In the qualitative results, three themes emerged from FGDI: 1) interest in learning, 2) acquisition of knowledge, and 3) finishing tasks in time. Each theme is presented below using learners' narratives.

Theme 1: Interest in learning

The main excerpts describing learners' attitudes and interests consisted of words such as: boring, not fun, easily forgettable, and difficult. Learners' verbatim quotes are presented here below:

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FGDI 1: "Learning Life Sciences in boring and it is not an interesting subject". CG
FGDI 3: "The subject is boring. We study for a pass only, and it is not even fun." CG
FGDI 4: "This time I found Life Sciences interesting since we learnt Plant Biodiversity using simulations." EG

Theme 2: Acquisition of knowledge

From the discussions, learners indicated learning using CS assisted them to comprehend Plant Biodiversity concepts better than before. Learners could replay simulations at their own time to master the content.

FGDI 1: "I discovered Life Sciences interesting, I remember everything regarding the content in the class using CS."EG.

However, learners had challenges in remembering the taught content.

FGDI 2: "We forget the taught content, and are unable to share the content we learnt" CG

Theme 3: Finishing tasks on time

When learners were asked to comment on the strategy used in teaching, the following direct quotes from FGDI are presented here below:

FGDI 3: "I enjoyed Life Science lessons because I spend more time studying Life Sciences" EG
FGDI 4: "We do not cover all expected topics as specified in the pacesetter and it is hard for us preparing to write exams." CG

Discussion

This study explored the effect of CS on Grade 11 learners' performance in Plant Biodiversity. The results show learners in the EG_1 achieved significantly higher scores than learners in the CG_1. The study showed statistically significant differences in the performance between learners taught using CS compared to those taught using TCM. This suggests hypothesis one stating learners in the EG taught using CS perform better than those in the CG taught using TCM is accepted. Our findings agree with Ragasa (2008), who showed computer-assisted teaching and learning is more effective than TCM. When teaching using CS, learners are accountable for their learning. Learning occurs through different levels where learners assess themselves and concentrate on meaningful learning. This observation agrees with the constructionists' theory, where learners use their environment to enhance their existing knowledge to learn effectively (Vygotsky, 1978). In fact, Gonczi et al. (2017) stated that CS teaching is twice as effective compared to TCM. It is no wonder learners using CS performed better than learners taught using TCM.

The results show EG learners taught using CS scored higher than CG learners taught using TCM (Figure 1 a). EG learners worked together to enquire, improve their cognition, and interact with their peers to study Plants Biodiversity. This observation agrees with the social constructivism theoretical framework where learners interact with objects and their peers to learn. Similarly, the technology used blended well with the pedagogy and content knowledge in teaching EG using CS. Technology also offered a conducive learning environment that facilitated interest, collaboration, and social construction of knowledge. Learners in EG scheduled their time to access CS on the school premises, so learners self-regulate their learning. It is a unique finding because no studies on high school biodiversity have been reported in the South African context.

There were no statistically significant differences in mean scores of male and female learners (Figure 2). It can be concluded that both boys and girls achieved similar conceptual understanding when taught using CS. Thus, hypothesis three which states that boys' and girls' performances in EG vary is rejected. The findings concur with the studies by Okwuduba et al. (2018) and Mihindo et al. (2017), who investigated the impact of computer simulations on gender and found no significant differences among male and female secondary school learners' performance in stoichiometry. They attributed the improvement to computers used in the activities. Fraser and Walberg (2005) contend that using technologies in teaching improves learners' performance.

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Learners in CG did not perform as well as EG because they might have lacked the enthusiasm to learn Life Sciences as it was rated as boring. Conversely, learners from EG found CS very interesting. These observations agree with Yildirim and Sensoy (2018), who indicated dynamic interactive visual representations are necessary to enhance academic performances and learners' interests. They further alluded that attitude is one of the critical factors determining learners' performance in science. EG group learners regarded the lessons as interesting and remembered what they had learnt using CS. This account was clear when learners shared information among themselves after the lesson presentations. The improvement in conceptual understanding corroborates with Popil and Dillard-Thompson (2015), who found simulations enhanced learners' knowledge acquisition. On the one hand, EG learners indicated that using CS helped them cover a wide scope quickly, giving more time for revision. On the other hand, learners from CG were frustrated because they did not complete the curriculum. Popil and Dillard-Thompson (2015) highlight using TCM limits learners' academic success by depending on teachers. If the teacher is not at school, learners study nothing during that time. Besides, teachers may hamper the academic performances of gifted learners. It is unlikely that teachers would revise all the content with learners.

Comments from EG show learners were excited about the use of CS to cover the scope with confidence. The excitement may have increased their desire to do more and achieve more. These results support the TPACK theoretical framework where instruments' interaction with social beings yields high performance (Koehler et al., 2014). Few studies in education used the Solomon Four Design in a developing country like South Africa. Learners scheduled their time to access CS on the school premises, so it can be concluded that learners developed Self-Regulated Learning (SRL). This study is unique because no studies on biodiversity at high school have been reported in the South Africa context. This study contributes to encouraging teachers with technology phobia to gain the courage to use ICT to teach science. Teachers in developing countries may adopt the use of CS to teach science like their counterparts in the developed countries. This is very vital, especially during the COVID-19 pandemic and possibly post COVID-19 era, where virtual learning is inevitable.

In the developed countries, each learner has a computer to use during studying. It is not the case in developing countries like South Africa, where a computer is shared among many learners. While using CS increased learners' performances with four to five learners sharing a computer, it is unclear how many learners per computer will be needed before compromising the positive effects. The effect of many learners sharing one computer was not investigated but may interest researchers. Also, a comparative study of the use of CS between the developed and developing countries needs further studies. The limitations of the study were: 1) few learners 33 per group may not be a true representation of the population, and thus there is a need for studies with larger samples for more reliable results; 2) learners were from one geographical region which may have limited the level of performance; 3) the simulations could not be done individually due to lack of home computers; and 4) the time for the study was short, which may have disadvantaged slow learners.

Conclusions and Implications

Learners taught using CS performed better than their counterparts taught using TCM. It has been established that CS are effective tools for enhancing learners' performance. The study confirmed CS did not discriminate against gender because both males and females in the EG performed equally well, but not learners taught using TCM. These results imply that the Department of Education should equip schools with computers and build teachers' capacities to embrace simulations in science teaching. When learners are provided with computers, they can develop interest and autonomy in science learning and this is relevant when considering the online teaching in the New Normal during and after the COVID-19 pandemic. These results may provoke other researchers to extend the study by involving larger samples from diverse geographical representations and use simulations in different subjects and topics. In addition, teachers' attitudes towards CS and a comparative study regarding the effect of learner-computer ratio may need further study.

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Declaration of Interest

Authors declare no competing interest.

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PRE-SERVICE TEACHERS' VIEWS ABOUT ECOSYSTEM-BASED FIELDWORK IN TERMS OF THE NATURE OF ENVIRONMENTAL EDUCATION, INVESTIGATIONS, SKILLS AND PROCESSES

Leonard Molefe,
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Abstract. *Today science teachers are expected to understand the nature of environmental education, and be competent in skills, methods, and procedures relevant to a science discipline. The purpose of this research was to explore pre-service science teachers' views with regard to environmental education, investigation conducted during a freshwater ecosystem studied, skills developed and the associated stepwise scientific process. Data were collected through a five-item questionnaire that included the characteristics of environmental education, types of scientific investigations, science process skills and the scientific process. 94 students that registered for a Bachelor of Education degree participated in this research. The results from statistical analysis of the teachers' responses showed the importance of life-long learning, involvement of community in environmental education and development of critical and problem-solving skills. However, most teachers could not provide correct scientific investigation they conducted during the freshwater study. Although there were no correlations between the investigation, science process skills and the associated scientific process, influence of the stepwise scientific process recommended in the science curriculum was evident in the teachers' linking of form a hypothesis to observation. The findings imply that teachers face potential challenges in understanding of scientific investigations and the scientific process.*

Keywords: *fieldwork, environmental education, pre-service teachers, science process skills, scientific investigations, stepwise scientific process*

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Introduction

Environmental education (EE) had long advocated a multidisciplinary view of an environment, acquisition of skills, knowledge, values, attitudes and solving of environmental problems (UNESCO, 1980). Today programmes related to EE could also be viewed as instrumental in the acquisition and development of skills, affective domain, and human-ecosystem connections (Powell et al., 2019). This is reasonable because explanations based on change in natural systems on earth are key in the understanding of the scientific concepts, processes, and tracing of the origins of environmental issues (Anand, 2013). Amid the issues thereof, EE has since presented a new challenge to teachers (Reddy, 2011), hence a need for the development of their expertise and enthusiasm (Lock, 2010). Thus, it can be argued that acquisition, for instance, of skills, understanding of scientific concepts and of the characteristics of EE, need to be prioritised and developed in appropriate and/or relevant settings to enhance their retention by teachers. Dresner et al. (2014) suggested that with regard to learning and retention of knowledge of the ecosystems, laboratory work and lectures may be supplemented with experiences that are based on field-based research and modelled the scientific process. This argument is reasonable considering that the scientific process is a model to problem solving, particularly in science. It melds with science process skills (SPS), which according to Gultepe (2016) are considered key to science education.

In EE there have been methods and processes to support change-oriented learning towards better environmental sustainability practices and/or environmental learning in a wide range of contexts in South Africa (Fundisa for Change Programme: FCP, 2013; Rosenberg et al., 2008; Shava & Schudel, 2013; Vogel et al., 2013). The learners studying science are expected to critically show responsibility towards the environment and also develop scientific skills and processes associated with investigating natural phenomena (Department of Basic Education: DBE, 2011). Sadly, teachers who are entrusted to develop learners' educational outcomes remain part of education problems in South Africa (Spaull, 2019). In relation to EE, there has been emphasis on the capacity of teachers to implement it (EE) in the curriculum (Reddy, 2011;

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FCP, 2013). One would expect such teachers to have competence, for instance, in the knowledge, skills, values, principles, methods and procedures relevant to disciplines (Molefe et al., 2016) such as EE. For these teachers to show such competence, they should understand and value scientific inquiry (J. Lederman et al., 2018). They should also show interest in science and environmental awareness, as well as proficiency in scientific knowledge (FCP, 2013). Most importantly, they should understand that fieldwork is a signature pedagogy for future outdoor EE teachers (Thomas & Munge, 2017), as it also accommodates scientific inquiry (Remmen & Frøyland, 2014).

Literature Review

The most influential work related to EE can be traced as far as the Tbilisi Conference (Reddy, 2011; Charoensilpa et al., 2012). EE was then envisaged as an action-based tool of teaching in which development of awareness, knowledge, skills and attitudes "assume[d] their full significance with the problems of the environment" studied through excursions, field work, and study trips (UNESCO, 1980, p. 44). Years on, an emphasis has also been on EE research and the associated study of ecological and issue-related scientific knowledge, empowerment of learners and study of curricula material (Scott, 2009). In other words, EE may be viewed as a key to environmental awareness - a phenomenon supported by Littledyke (2008), Moyo and Masuku (2018) and Soto-Cruz et al. (2014). Furthermore, it (EE) may point to the synergy between inquiry-based learning and ecology (Taylor & Bennett, 2016) as well as the scientific process (Tang et al., 2009; Thomas, 2012) within the context of science education. Finally, it may involve ecology-based training for a pre-service teacher (Gülüm, 2011) and thus development of ecology-based content and SPS (Colley, 2006).

It should be noted that the quality of teachers determines that of an education system (Spaull, 2019). Therefore, it is reasonable that practice of EE showed that the associated programmes that support teachers are key (Eames et al., 2008; FCP, 2013; Reddy, 2011). Thus, EE should be part of science teacher's education for its (EE) characteristics to be enshrined in science education. That said, the definition of the environment itself has long evolved and can now be explained in broader terms (Reddy, 2011). Teachers need to understand the multidisciplinary nature of the environment before they engage in EE. EE itself entails environmental knowledge, which in turn encompasses knowledge and awareness about environmental issues the world is confronted with today as well as the solutions (Boca & Saraçli, 2019). Thus, the researchers contend that in science education it is important that prior to blending EE with scientific investigations, the scientific process and the associated SPS, teachers' views about its (EE) characteristics are illuminated. Sondergeld et al. (2014) argued that EE should not only integrate multiple content areas but also make education relevant, use social context and promote *lifelong*, forward-looking education. The proposition of lifelong education points to one of the initial characteristics of EE that teachers should understand. The other characteristics include integration of education into community and the interdisciplinary and holistic nature of EE even in its application (Molefe & Aubin, 2021). Its approach to solving problems (another characteristic) dovetails with Ntanos et al.'s (2018) arguments about EE benefits in terms of critical thinking skills and problem-solving skills.

Fieldwork remains a long-standing pedagogy across a range of disciplines in higher education institutions (HEIs) (Thomas & Munge, 2017). It is considered one of the leading mechanisms for teaching and learning and doing science (Allen, 2014). It may also be a relevant method in an "*ecosystem* study…a *water pollution* test, a *biodiversity audit* and *general observations*…" (Rosenberg et al., 2008, p. 2; emphases added) that may be central to enabling pre-service teachers make connections between the domain of observable(s) and that of ideas. The implication is that teaching about ecosystems might provide an opportunity for inquiry learning (Taylor & Bennett, 2016). This explains why the popularity of fieldwork is rooted in its ability to accommodate inquiry-based learning in which students may engage in scientific investigations (Remmen & Frøyland, 2014), understand ecology content knowledge (Colley, 2006) such as that related to biodiversity and pollution (Shava & Schudel, 2013) and SPS (Molefe et al., 2016). In other words, by incorporating scientific inquiry in fieldwork in EE, teachers are first helped to engage in scientific investigations, depending on types or research questions (N. G. Lederman et al., 2013). Secondly, the teachers may be able to apply scientific knowledge in interdisciplinary context. Thirdly, drawing from Ozdem-Yilmaz and Cavas (2016), teachers may also have an opportunity to consolidate scientific processes with scientific knowledge, scientific reasoning and critical thinking to advance scientific knowledge associated with EE. Educators' understanding of scientific inquiry and scientific investigations remains relevant even today. This is even more important considering that the issue of the scientific method and SPS are enshrined in these two concepts (J. Lederman et al., 2018). Thus, it can be argued that the inclusion of scientific investigations in the present research

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was important because teachers' development of SPS might be necessitated through them (scientific investigations). The success of the development of SPS may form the basis for their understanding of how SPS blend with the scientific process within an equally understood context - EE.

The role of teachers in their students' development of SPS cannot be overemphasised (Saban et al., 2019). Literature review shows that while SPS remain the key part of research over the last 10 years (e.g., Gultepe, 2016; Molefe & Stears, 2014; Silay & Çelik, 2013; Tilakaratne & Ekanayake, 2017; Yakar, 2014), they (SPS) had long been central to debates on processes and content (Millar & Driver, 1987; Wellington, 1989; So, 2003). Molefe et al. (2016) have elucidated on the debates around teaching and/or development of SPS, conceptual understanding and context. Gultepe (2016) contended that as teaching science encompasses the content and processes and skills, "underestimating content over process or process over content is unacceptable", as both are equally important (p. 780). As referred to earlier, SPS (and thinking or critical thinking skills [Foskett, 2000; Taylor & Bennett, 2016]) can be part of a study of ecosystems (VanLeuvan & MacDowell, 2000). Despite criticisms around SPS, their development may improve teachers' understanding of environmental concepts today (Cf. Irwanto et al., 2018). Use of an integrated learning strategy may be effective in developing teachers' SPS and awareness of the river environment (Winarti et al., 2018). Thus, SPS should be linked to EE and engaged in and developed subsequent to conceptual understanding such as understanding of environment in a broader sense using a suitable teaching and learning strategy. Most importantly, they should be linked to the scientific process itself.

Frameworks for EE, Scientific Investigations, SPS and the Scientific Process

Suitable frameworks were needed in the present research because there are various views about concepts used such as EE, scientific investigations, SPS and the scientific process (scientific method). Indeed, literature has different lists of the *characteristics of EE* (e.g., Baez et al., 1987; Charoensilpa et al., 2012; UNESCO, 1980), *SPS* themselves (e.g., DBE, 2011; Gultepe, 2016; Molefe et al., 2016; Saban et al., 2019), *science processes* (DBE, 2011; Moeed, 2013; So, 2003; Watson & James, 2004), as well as *scientific investigations* (Moeed, 2013; So, 2003; Watson et al., 1999).

For teachers to be able to explain natural phenomena scientifically, they should have an environmental awareness (e.g., of the nature of EE). They should not only know the goals and purposes of science investigations but also the types of scientific investigations (Moeed, 2013; Watson et al., 1999). In order to contextualise the present research, the researchers drew from UNESCO (1980), Baez et al. (1987) and Watson et al. (1999) to devise frameworks that might act as a lens for this research with regard to the characteristics of EE and the types of scientific investigations (Table 1).

Table 1
The Nature of EE and Types of Scientific Investigations

Characteristic features of EE	Types of scientific investigations
1. It is a life-long, forward-looking education.	(1) Fair testing and comparing
2. It involves integration of education into the community.	(2) Pattern seeking
3. It is interdisciplinary and holistic in nature and its application.	(3) Classifying and identifying
4. It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	(4) Exploring

As humanity ventures into the 4th Industrial Revolution with its glaring grand challenges, the importance of SPS and environmental awareness cannot be overemphasised, especially in teacher education. Sadly, there are also misconceptions about the associated scientific process, and fair testing is at the centre of them (Moeed, 2013; DBE, 2011). Thus, the misconception around fair testing needed to be diagnosed and corrected. For a framework on skills and the scientific method, they drew from SPS, and the stepwise scientific process stipulated in the South African Natural Sciences curriculum (DBE, 2011). Furthermore, they drew from Molefe and Stears (2016) and Watson and James's (2004) ideas to show how such skills may blend into those scientific processes (Figure 1).

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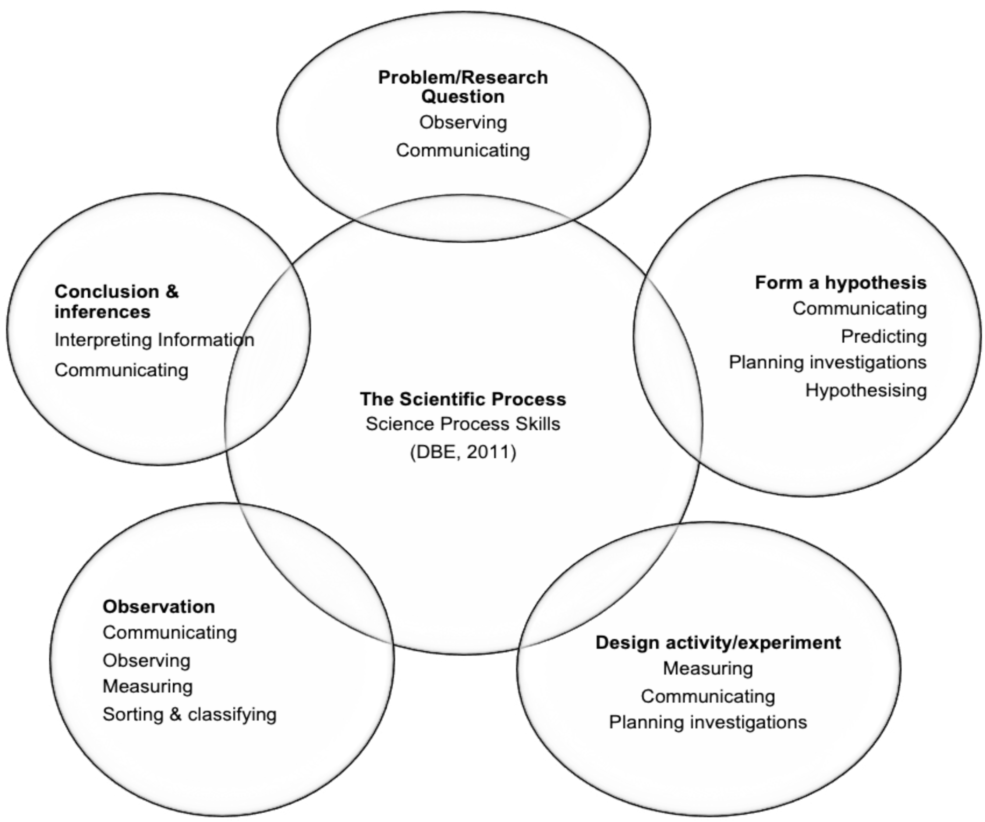
Research Aim and Research Questions

The aim of this research was to explore pre-service teachers' views in relation to the characteristics of EE itself, scientific investigations, SPS they developed and the associated scientific process. Many studies analysed by Álvarez-García et al. (2015) have pointed to teachers' indisputable role in "the infusion of EE into schools as a tool to environmentally educate future citizens" (p. 81). Teachers have also been at the heart of empirical work on biology field work for decades (Lock, 2010; Tilling, 2018). Thus, the present teachers were a perfect fit for the research. They studied EE in their Life Sciences module offered at an institution in KwaZulu-Natal, the components of which comprise annual three-day fieldwork in which different ecosystems that include freshwater are investigated. The research has focused on the freshwater ecosystem because it enabled the researchers explore all the key aspects they sought to study.

The research reported here has been more imperative than ever. Global problems and threats in our time include the environment and climate (Ivanov, 2018). Thus, it is important that scientific literacy, interest in science and inquiry-based instruction are incorporated in programmes intended to increase school students' environmental awareness (List et al., 2020). Freshwater is part of a nexus that is proposed as a tool to transform human well-being in Southern Africa (Mabhaudhi et al., 2019; Mpandeli et al., 2018). This is reasonable because about 60% of water used in, for instance, mining and the associated mine dumps and landfills impacts on freshwater, hence biodiversity (Department of Environmental Affairs, 2018). Furthermore, it is through EE in higher education that future teachers could be prepared for a green society today (Boca & Saraçli, 2019). Most importantly, this research was part of a project that investigated pre-service teacher learning within science and technology education modules (Molefe et al., 2017), and our latest work on SPS and the scientific process intertwined with global environment issues today.

Figure 1
The Scientific Process and the Associated Science Process Skills



Note. Adapted from Molefe and Stears (2016)

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The research sought to answer the following research questions in relation to an EE module:

- What characteristic features of EE were embedded in the pre-service science teachers' fieldwork?
- What type of scientific investigations were conducted by the pre-service science teachers during their freshwater study?
- What correlations are there between the teachers' views of a freshwater ecosystem in terms of scientific investigations, processes and the associated SPS used?

Research Methodology

General Background

This research adopted a quantitative research approach. The approach allowed the researchers to utilize survey design (Neuman, 2014). Survey designs normally provide a numeric description, for instance, of trends or opinions of a sample of a particular population (Creswell, 2014), which include correlations among variables (Cohen et al., 2018). In this research, a survey administered was descriptive and analytic in relation to the teachers' views about EE, scientific investigations, SPS and the scientific process within the context of the freshwater study. A questionnaire was employed because it is commonly used in SPS-based studies (Fugarasti et al., 2019). Furthermore, it was utilised in this research because it could elicit teachers' views about scientific processes and skills (Coil et al., 2010) and scientific investigations (Moeed, 2013). It could also be used to study learners' understanding of scientific inquiry (J. Lederman et al., 2018).

Participants

Data were collected from 94 pre-service teachers who were registered for a second-year Biological Sciences Education module at the institution. The sample size gave a fairly good reliability because the minimum one (size) that could be used for some statistical analysis is 30 (Cohen et al., 2018). Nevertheless, it should also be noted that this conveniently selected group of teachers completed the questionnaire as part of their fieldwork exercise. Thus, the sample selection might have weakened the research's external validity. The research questions and design of the research were not based on the demographics of the teachers such as those related to gender and age. Thus, these variables were not included. Coil et al. (2010) pointed to the importance of a scaffolding approach and iterative practice, particularly in relation to SPS. The approach and the practice were essential before the present teachers could provide views about EE, scientific investigations, SPS and how they meld with the scientific process steps. Thus, the teachers were suitable participants because they had at least 18 months' exposure to SPS during the relevant method and content module classes and the associated practical activities. These teachers were assured of absolute anonymity.

Instrument and Procedures

A five-item questionnaire created by the researchers was used to establish the teachers' views in relation, for instance, to EE itself, scientific investigations, the scientific process, and development of SPS. The questionnaire, with attached copies of the detailed description of SPS and the scientific process steps (DBE, 2011), and information about EE and scientific investigations, had qualitative and quantitative components. Questions *one* and *two* of the questionnaire provided qualitative data on activities the teachers found interesting with regard to the ecosystems they studied, and the descriptions of EE characteristics they learnt, respectively. The *third, fourth* and *fifth* questions provided quantitative data on scientific investigations, SPS, and SPS and the scientific process. In elaboration, with regard to the last three questions, the teachers were expected to select the types of scientific investigations they thought they used during the freshwater study. Second, they selected five SPS used to deduce the quality of the freshwater ecosystem studied. The teachers also provided activities that developed the SPS thereof. Third, they selected two SPS that they viewed to fit into the scientific process steps when investigating the freshwater ecosystem using the chemical test kits. The research explored correlations between the teachers' responses to the questions except the first two.

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Survey research is prone, for instance, to measurement and nonresponse errors (Ponto, 2015). Thus, piloting a questionnaire might be useful in addressing issues related, for instance, to clarity and elimination of questions' ambiguities (Cohen et al., 2018). In this research, a pilot test of the questionnaire was conducted with a tutor and ten demonstrators who successfully completed the module. It should also be noted that Molefe and Stears's (2016) findings on SPS, the scientific process and the scientific inquiry were further used to improve the questionnaire for the research. In addition to the improvements made (e.g., the questionnaire sectionalization and itemization), the results of the pilot test were used to revise the questions of the questionnaire where necessary. For example, *investigations* were reworded into *scientific investigations*. The teachers were further requested to provide details concerning SPS they developed during the freshwater study (see the questionnaire's Table 2) and an example was given to enable them to successfully complete the last question on the questionnaire (see the questionnaire's Table 3).

The questionnaire was administered during a fieldwork period. Ethical clearance for the project investigating pre-service teacher learning within science and technology education modules at the institution was used.

Data Analysis

Cohen et al. (2018) pointed to the importance of data entry and cleaning. Such processing of data was conducted using OpenRefine. The data required a statistical package that could enable the researchers to compute descriptive and analytical functions essential to answer the research questions. R was used because of its extensive application in statistical and graphical techniques. For questions concerning EE's characteristic features and type of investigation performed by the teachers, the researchers needed to verify that the answers were not given randomly. Thus, the preliminary results were based on Chi-squared test on the frequencies. Then, Kendal and Pearson correlation tests were used to measure the degree of the relationship between variables of the questions. The tests were corrected using a Bonferroni correction.

Research Results

This research sought to illuminate the teachers' views of the characteristic features of EE (EECF) and scientific investigations prior to exploring those related to SPS and the scientific process. It was important that a test was made to check whether the answers concerning these two variables were given randomly. Chi-squared test was used to compare the given answers to uniform (random) ones. The respective *p*-values (Table 2) show that the answers for EECF and scientific investigations were not given randomly.

Table 2
p-values of Chi-squared test for uniformity for EECF and scientific investigations

Variables	$\chi 2$	*df*	*p*-value
EECF	32.9	4	< .001
Investigations	57.5	5	< .001

Characteristic Features of EE that Were Embedded in the Pre-Service Science Teachers' Fieldwork

One of the activities that were part of the teachers' fieldwork was a collaborative development of critical thinking skills within the context of nature conservation and sustainability. Hereafter, they were expected to describe any two EECF (Table 1) they had developed before the researchers assessed, for instance, their SPS and values essential for solving environmental problems today.

The uniformity test was followed by further exploration of the dataset. Table 3 shows that the following pair of EECF were given most often: *It is a life-long, forward-looking education* and *it involves integration of education into the community*. These characteristics together with *It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills* resulted in the second and third most given pairing, respectively. Some of the written descriptions associated with the results were:

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Table 3
Frequency Table for EECF

EECF	Frequency
It is a life-long, forward-looking education and it involves integration of education into the community.	29
It is a life-long, forward-looking education and it is interdisciplinary and holistic in nature and its application.	5
It is a life-long, forward-looking education and it encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	27
It involves integration of education into the community, and it is interdisciplinary and holistic in nature and its application.	2
It involves integration of education into the community, and it encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.	24
It is interdisciplinary and holistic in nature and its application, and it is interdisciplinary and holistic in nature and its application.	3

EECF 1 (see Table 1): *It [EE] is always being updated and the information added because new species…are forever discovered by people and studied* (Teacher 1).
EECF 2: *This involves…people taking responsibility of the environment that they live in. This can be done through summits, and programmes could arise that teach people about conservation of nature and sustainability in the community* (Teacher 2).
EECF 4: *Lectures give us platform to gather information for ourselves…This develops and stimulates [sic] our problem-solving and critical thinking skills…Fieldwork taught us awareness and sensitivity to nature; to value every species…* (Teacher 3).

Scientific Investigations that Were Conducted by the Pre-Service Science Teachers during Their Fieldwork

The freshwater study was intended to build on practical and theoretical emphases on scientific investigations done at the institution. The present teachers' reflections on scientific investigations (Table 1) done enabled the researchers to explore this. The results (Table 4) showed that *Classifying and identifying* (92), *Exploring* (73) and *Fair testing and comparing* (62) were given most often.

Correlations Found Between the Teachers' Views of a Freshwater Ecosystem in Terms of Scientific Investigations, Processes and the Associated SPS Used

Teachers should be primary creative and critical thinkers concerning solutions to societal issues today. Hence, investigating a nexus of scientific investigations, the scientific process steps and SPS was imperative. The researchers acknowledge that, similar to EECF and scientific investigations, it was important that they presented their findings concerning SPS and the scientific process before those related to correlations between these two variables thereof and the investigations. Nevertheless, it should be noted that this research was a follow-up to one in which they (researchers) studied the present teachers' views about how SPS blend with the scientific process (Molefe & Aubin, 2021). Thus, in this research they chose to focus solely on correlations between several variables (Table 5).

Table 4
Frequency Table for Scientific Investigations

Types of scientific investigations	Frequency
Fair testing and comparing	62
Pattern seeking	31
Classifying and identifying	92
Exploring	73
Making things or developing systems	6

Note. The students could give more than one answer. Only the marginal frequencies of the given answers were considered.

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The researchers computed Kendal's rank correlation tau (τ) and Pearson's product-moment correlation (r) to determine the relation between the variables. The results of the Kendal correlation showed that there was a significant positive association between *Form a hypothesis* and *Observation* ($\tau = 3.28$, $p = .001$). Pearson correlation also indicated the same association between the two variables thereof, which was also statistically significant ($r = 3.53$, $p = .001$). This means that correlations between the number of incorrect answers related to *Form a hypothesis* and *Observation* were significatively greater than zero.

In relation to SPS, the researchers drew a bar plot of the incorrect answers (i.e., answers far from Figure 1) given by the teachers (Figure 2). The results showed that all the teachers provided less than two incorrect answers out of five answers related to the SPS *observing*, *comparing*, *recording information,* and *communicating*, which is a good result. For random answers, they computed the same bar plots of incorrect answers (Figure 3).

The results indicated higher values (from 1 to 5), which shows that answers given by the teachers were clearly better than random answers. The researchers then tested for correlations between incorrect answers given by the teachers and those (number of incorrect answers) concerning the other variables (Table 5). The findings could not show any correlations.

In relation to scientific investigations, the findings could not show significant correlations between the number of incorrect answers given by the teachers and the number of mistakes concerning the other variables.

Discussion

The concept of EE (Baez et al., 1987; Reddy, 2011; UNESCO, 1980), development of skills and knowledge concerning the environment (Colley, 2006; VanLeuvan & McDowell, 2000) or using environment (and ICT) (Osman & Vebrianto, 2013), the scientific investigations (Watson et al., 1999) and teachers' perspectives thereof (Moeed, 2010) and controversy around the scientific process (Thomas, 2012; Watson & James, 2004) are hardly modern. Nevertheless, EE in tandem with sustainable development have become part of recent key debates on environment at local (Mabhaudhi et al., 2019; Mpandeli et al., 2018) and international levels (Boca & Saraçli, 2019). Research over the last five years has also focused on SPS and achievement (Prayitno et al., 2017), SPS assessment using scenario based MCQs (Temiz, 2020), understanding of SPS (Shahali et al., 2017), phases of inquiry (Pedaste et al., 2015) and inquiry skills by future biology teachers (Čipková & Karolčík, 2018), context and the debates around teaching and/or development of SPS, and conceptual understanding and context (Molefe et al., 2016). However, teachers' views of the freshwater ecosystem in terms of EE, scientific investigations, processes and the associated SPS they used remains a domain that is hardly been ventured into. This research sets a precedent of aspects that another research may learn from.

Table 5
Correlation Matrix for the Scientific Process, SPS and Scientific Investigations

	Research question (ReQ)	Formulating hypothesis (FoH)	Designing experiment (DeE)	Observations (Obs)	Conclusions (Con)	Science process skills (SPS)	Scientific investigations (Inv)
ReQ	1.000	-.212	-.004	-.121	-.059	.011	.045
FoH	-.212	1.000	.038	.345	-.020	.086	.207
DeE	-.004	.038	1.000	-.212	.224	-.062	.037
Obs	-.121	.345	-.212	1.000	-.019	-.080	-.145
Con	-.059	-.020	.224	-.019	1.000	.024	-.131
SPS	.011	.086	-.062	-.080	.024	1.000	-.055
Inv	.045	.207	.037	-.145	-.131	-.055	1.000

Note. The Bonferroni correction, .05/21 = .002, enabled the researchers to reject a null hypothesis of randomness if the p-value was less than .002.

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Figure 2
Bar Plot of Answers from the 94 Teachers

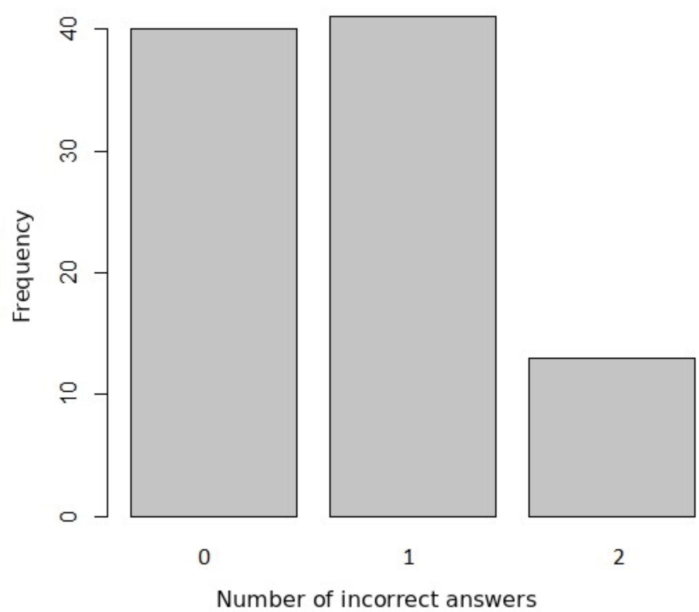
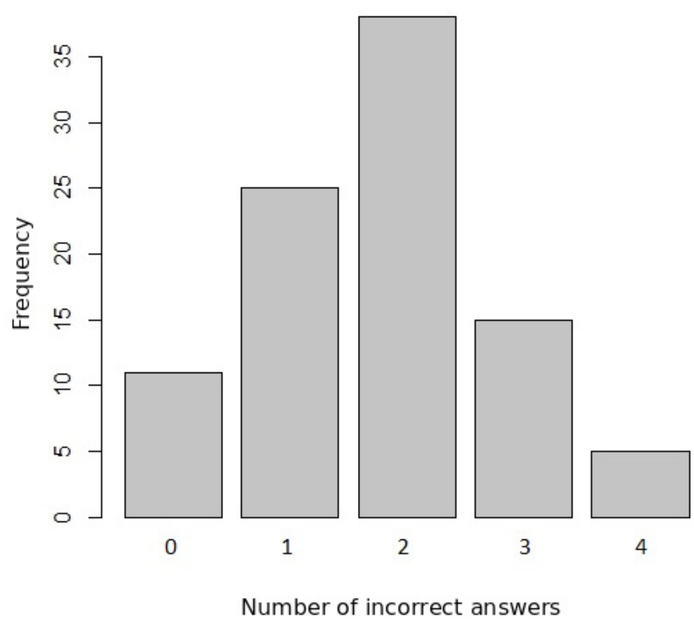


Figure 3
Bar Plot of Random Answers from the 94 Teachers



EE might be instrumental in the delivery of various benefits related to natural ecosystems (West, 2015). An environment itself can be used to develop SPS (Osman & Vebrianto, 2013). Thus, it can be argued that studies related to natural ecosystems should include investigations using SPS. Students' ecosystem-based worksheet might not only be practical, but it could be used to enable them to develop SPS (Patresia et al., 2020). The present teachers engaged in a fieldwork where activities included the use of a worksheet and several resources such as bug dials to investigate the quality of the freshwater ecosystem. They were also challenged to reflect on characteristics of EE they developed

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and the scientific investigations they employed as the basis for development of SPS using a stepwise scientific process.

The present teachers viewed EE as *a life-long, forward-looking education* that *involves integration of education into the community*. They went further to pair these characteristics of EE with *It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills*.

Extensive literature reviewed by Álvarez-García et al. (2015) pointed to challenging issues around environmental competences and the associated teacher training. The researchers were conscious of such challenges in the present research. Thus, the freshwater study was set to nourish life-long environmentally literate habits such as outdoor experience and collaborative work on meaningful environmental issues (Sondergeld et al., 2014). They also tapped into the teachers' critical thinking skills in terms of nature conservation and sustainability in tandem with communal and ecosystem-based impact of mining where they conducted their fieldwork. The associated activity also tapped into their sensitivity, awareness and conscience and reinforced the theoretical EE aspects developed at the institution. The impact, for instance, of critical thinking (Arslan, 2012; UNESCO, 1980), the need to raise awareness of sustainable development and understanding of environment in a broader sense (Reddy, 2011) had long been associated with EE. The results of the present research may thus be understood with regard to guided inquiry and problem-solving processes as the means for life-long learning (Burbules et al., 2020), the importance of development of skills of life-long learning in promoting sustainability (Yli-Panula et al., 2020), critical thinking and problem-solving as key aspects in sustainability and for future success and survival (Taimur & Sattar, 2020) and the need to raise awareness about key issues facing the planet today.

The importance of an iterative approach to science investigations and the associated SPS, conceptual understanding and reflexivity cannot be overemphasised (Chirikure, 2019). It is thus reasonable that there has long been a call for research on understanding of scientific inquiry rather than mere "doing" of it (inquiry) (N. G. Lederman et al., 2013). The experience of developing SPS during the freshwater study was meant to provide the teachers with a framework and understanding of scientific investigations. The results showed that *Classifying and identifying*, *Exploring* and *Fair testing and comparing* dominated the selections made by the teachers. It should be noted that the teachers drew from *observed* indicator species to deduce the state of the freshwater ecosystem they studied. They captured, *identified,* and *classified* those species according to their sensitivity to pollution using resources provided.

An investigation phase of inquiry may be characterised by "explore" or "exploration" (Harlen, 2014; Pedaste et al., 2015). It should be noted that understanding scientific inquiry itself has been a challenge for teachers and learners (J. Lederman et al., 2018). *Exploring* (Table 4) involves making careful observations over time (Watson et al., 1999, 2006). Exploring might not be as common as fair testing and classification in the later years of an education system (Moeed et al., 2016). Thus, the wrong selection of *Exploring* by the present teachers may be understood in terms of investigating (rather than making observations of) indicator species to deduce the state of the freshwater ecosystem studied. This finding, by virtue of being the second most selected type of scientific investigation, requires further research. On the other hand, the incorrect *Fair testing and comparing* may be understood in terms of emphasis on scientific investigations in the South African Natural Sciences curriculum that are tailored to fair testing (DBE, 2011). Bias towards fair testing is also found in Hume and Coll (2010) and Moeed (2010, 2013). The present teachers' mixed views concerning the scientific investigation they developed suggest possible lack of or limited experience of scientific investigations in high school (Kazeni et al., 2018; J. Lederman et al., 2018) and/or at tertiary level (Molefe & Stears, 2014). That might have, in turn, impacted on their understanding that there is *no* linear approach to solving problems, especially those related to the environment in a broader sense. The researchers believed that such a deficiency might also impact on the teachers' conceptual understanding of SPS and the scientific process, both of which are equally emphasised in the curriculum. But there was no correlation between incorrect answers given by the teachers on scientific investigations, SPS and the scientific process.

Teachers' understanding of scientific processes might be a fundamental facet of thinking synonymous with science and EE - a reason SPS could also be considered as life-long learning skills (Temiz, 2020). Molefe and Aubin's (2021) results from statistical analysis of the present teachers' responses to skills they developed during freshwater study showed prominence of *observing.* This is a SPS that has been rated highly at the institution (Molefe et al., 2016). Furthermore, teachers might be successful in identifying the skill (Gultepe, 2016). In relation to the stepwise scientific process, the teachers' responses showed a good proximity to the expected representation of the scientific process model (Figure 1) with regard to *Form a hypothesis*. On the other hand, *Observation* showed a relatively close proximity to the model.

As referred to earlier, answers given by the teachers concerning SPS were better than random answers (Figure 3). Teachers' perceptions of understanding of integrated SPS such as *hypothesising,* might be high (Hafizan et al., 2012) contrary to their conceptual knowledge (Mumba et al., 2018). That said, there was no correlation between incorrect

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answers given by the present teachers concerning SPS and those concerning the other variables, including the scientific process steps (e.g., *Form a hypothesis* and *Observation*). A significant correlation was only evident between *Form a hypothesis* and *Observation*. Thus, the correlation merely enabled us to understand the direct link between the incorrect answers given by the teachers in relation to the scientific process steps. First, the link between the two steps may be understood in terms of the scientific process being viewed as making "*observations* to *test the hypothesis* and drawing a conclusion in support or otherwise of the tested hypothesis" (Moeed, 2013, p. 541; emphases added). The association of the two steps is also evident in the Natural Sciences curriculum (DBE, 2011; also see Figure 1). Teachers are expected to make inferences from their *observations*, make some conclusions, with their *hypothesis* in mind.

SPS have been extensively researched in literature. The popularity of SPS today is reasonable because they are not only the life-long learning skills, but their development is a fundamental goal of science education (Tamiz, 2020). They may enable teachers to not only understand information better, but also develop their critical thinking skills and decision-making (Hafizan et al., 2012). The environment remains an outdoor laboratory to develop them (SPS). Yet, research on their (SPS) association with scientific investigations, the stepwise scientific process and EE is very limited. Buchanan et al. (2019) argue that teachers need to make connections to the scientific method, real-world issues, learning and action when engaging with digital technologies for environmental purposes. Their argument, coupled with the current research's findings, suggest a sustainable future that will disrupt the notions of the science education curriculum.

Lortie's (1975) long-standing views about teacher educators' praxis and its impact on teachers' learning through own "apprenticeship of observation" have now assumed even greater importance. The present findings imply that teacher training should offer apprenticeship that embodies development of life-long skills and 21st century skills. The training should also value integration of education into the community.

It was interesting that there was only a link between two scientific steps - *Form a hypothesis* and *Observation*. Students might be confronted with some challenges when conducting scientific investigations (Ramnarain, 2011). Indeed, the present research suggested an influence of science curriculum on teachers' understanding of the scientific process and scientific investigations. Teachers need to understand the fundamental aspect of scientific investigations, that is, our observations of natural phenomena (and scientific investigations) are inspired and guided by problems or questions (N. G. Lederman et al., 2013). Therefore, not all scientific investigations would be based on formulated hypothesis as they (investigations) might be solely rooted in, for instance, the *Classifying and identifying* type (Table 1). For teacher educators, the findings pointed to a need for new ways in which they might better enable their students to reconcile the understanding of types of scientific investigations, SPS and stepwise scientific process.

Conclusions and Implications

The research showed that EE might be viewed as a life-long, forward-looking education that involves integration of education into the community. The research further pointed to the importance of the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills in relation to the two characteristics of EE thereof.

Classifying and identifying, exploring and fair testing and comparing were the common types of scientific investigations selected by the teachers although they simply observed, identified, and classified indicator species according to their sensitivity to pollution in the freshwater ecosystem studied. The results, particularly in relation to fair testing, indicate that the teachers did not succeed in providing the scientific investigation they employed. The results further show a significant relationship between the teachers' ability to formulate a hypothesis and observation.

In this research, it was concluded that EE within the context of teacher education should be characterised by skills development and integration of education into the community. Scientific investigations (and the scientific process) should be part of EE-based teacher education, particularly because teachers might have misconceptions about them. Thus, there is an urgent need for educational reform in higher education in relation to scientific investigations, pre-service teachers' understanding of SPS and how they (SPS) meld with the stepwise scientific process.

The present findings make a small but significant contribution to science education in terms of debates on the areas teacher educators should prioritise when investigating pre-service teachers' stance on EE, scientific investigations, scientific skills and processes intertwined with possible challenges related to the planet's natural ecosystems today.

Declaration of Interest

Authors declare no competing interest.

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BIOLOGICAL SCIENCE FOR EDUCATORS

EDUCATIONAL OUTCOMES DEVELOPED DURING LECTURES AND AT ISMANGALIZO

Student Name & Surname	
Student Number	

QUESTION 1: Please (a) **describe** the activity that you performed at *iSmangaliso that you found the **most interesting,** and (b) give **reasons** why you chose it.

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Note. *iSmangalizo is a pseudonym for a place where the students participate in annual three-day fieldwork based on five eco-systems (i.e., Freshwater, swamp mangroves, dunes, natural forest, and plantations) and nature conservation and sustainability activity.

QUESTION 2: The Nature of Environmental Education

Characteristics of Environmental Education
It is a life-long, forward-looking education.
It involves integration of education into the community.
It is interdisciplinary and holistic in nature and its application.
It encourages the development of sensitivity, awareness, understanding, critical thinking and problem-solving skills.

Please **briefly describe** any **two (2)** of the characteristics of Environmental Education stated in the table above. Your descriptions should be based on the **development of the two selected characteristics during lectures** (at university) **and fieldwork** (at iSmangalizo).

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QUESTION 3: Table 1 below shows different types of scientific investigations. Please tick **(✔) scientific investigation(s)** that you used during freshwater study at iSmangalizo.

Table 1 Types of scientific investigations

ITEM	List Of Types Of Scientific Investigations	Tick (✔)
3.1	Fair testing and comparing	
3.2	Pattern seeking	
3.3	Classifying and identifying	
3.4	Exploring	
3.5	Making things or developing systems	

QUESTION 4: Science process skills in Environmental Education

Please refer to the attachment on science process skills (SPS). It has SPS that you should have developed during the freshwater study.

Please **list** any **five (5) science process skills** (in **Table 2** below) that you developed during your fieldwork at iSmangalizo. You are also expected to **provide** an activity that you did to support your choice of the SPS.

Table 2 Science process skills developed at iSimangalizo

Science process skill I developed	The activity I did to develop this skill
1.	
2.	
3.	
4.	
5.	

QUESTION 5: During your freshwater study, you did not use Chemical Test Kits (CTK) for testing water quality at the stream studied. If you did, you would have followed the six (6) processes of science in Table 3 below.

Please refer to the attachment on science process skills (SPS). It has Science process skills (SPS) that you would have developed during the activity, now using the Test Kits.

Complete Table 3 by writing down **any two (2) SPS** that you would have developed in 5.1 to 5.6. **NOTE: I have done 5.2 for you as an example.**

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Table 3 Processes of science and the associated SPS

ITEM	PROCESSES OF SCIENCE PROCESSES OF SCIENCE	Two Science Process skills I would have developed
5.1	**Problem/Research question**: Identify a problem and develop a question. What is it you want to find out about the stream?	
5.2	**Research/Background knowledge:** What is it that you know about the stream from previous investigations/publications?	**Communicating** **Interpreting information**
5.3	**Formulating hypothesis**: A hypothesis is your idea, answer, or prediction about what will happen and why, when you test the state of the stream's water.	
5.4	**Design an activity or experiment**: Activities you to do to test your idea or prediction to see if you were right about the state of the stream.	
5.5	**Observation: (a)** Observe/note changes/reactions (e.g., change in colour of the chemical used), and record your observations (e.g., onto a graph, table, etc.), **(b)** look at the results of your activity or experiment, **(c)** and write about what happened.	
5.6	**Conclusion:** Make inferences about the observations recorded. Make some conclusions. What did you find out? Do your results support your hypothesis? What did you learn from this investigation?	

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THE EFFECTS OF INFORMATION AND COMMUNICATION TECHNOLOGY ENGAGEMENT FACTORS ON SCIENCE PERFORMANCE BETWEEN SINGAPORE AND TURKEY USING MULTI-GROUP STRUCTURAL EQUATION MODELING

Batuhan Özkan,
Fatma Noyan Tekeli

Abstract. *Information and Communication Technology (ICT) engagement, as a multidimensional construct, plays an increasingly important role in education. The main purpose of this research was to explore the effects of ICT engagement factors on science performance across Singapore and Turkey conditional to the sufficient degree of measurement invariance of ICT engagement scale. The multi-group confirmatory factor analysis results demonstrated strong factorial invariance of ICT engagement scale across Singapore and Turkey, so we were able to use ICT engagement scale to meaningful and valid comparisons between these countries. After obtaining measurement invariance, a multi-group structural equation modeling was used for the comparison of the effects of ICT engagement factors on student's performance of science between these two countries. While interest in ICT, perceived ICT competence and perceived autonomy in using ICT have significant positive direct effect on science performance in both countries, the direct effect of social relatedness in using ICT on science performance is negative in both Singapore and Turkey. Also, when compared with Singapore, the effects of all ICT engagement constructs on student's performance are higher in Turkey.*

Keywords: *ICT engagement, measurement invariance, multi-group SEM, science performance, PISA 2018*

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Introduction

The Program for International Student Assessment (PISA) conducted by the OECD in three-year cycles is an international large-scale program that measures 15-year-old students' knowledge and skills in reading, mathematics, and science. PISA compares the quality and equity of education across countries, and the results obtained are used by educators and politicians in determining appropriate education policies and practices (OECD, 2019a). In each cycle of the research, a subject is chosen as the main area. Like the previous cycles, the PISA 2018 assessment covered the areas of reading, mathematics, and science, but the core area was reading literacy.

In recent years resources related to ICT have become accessible to students both at home and at school and have gained a large place in modern society. Due to the importance of ICT, an optional ICT familiarity questionnaire about ICT availability, ICT skills and ICT use has been included in each cycle of PISA since 2000 (Kunina-Habenicht & Goldhammer, 2020). With the change in PISA 2015, ICT engagement questionnaire was added to PISA's ICT familiarity survey as a new structure and this scale was also included in PISA 2018. ICT engagement scale has been improved by both intrinsic and extrinsic motivation derived from the theory of self-determination (Deci & Ryan, 2000). ICT engagement scale has four factors: 1. Interest in ICT which is the intrinsic motivation of using products related to ICT (Zylka et al., 2015); 2. Perceived ICT competence, students' ICT-based knowledge and skills that can be used to perform ICT-related tasks (Meng at al.,2019); 3. Perceived autonomy in using ICT, perceived control and independence of an individual in using ICT; 4. Social Relatedness in using ICT, the measure of an individual communicating and interacting with others using ICT (Kuger et al., 2016; Zylka et al., 2015)

ICT engagement scale is a fairly new scale. While reviewing the literature, it was noticed that the early studies leading to this scale originated from the

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use of ICT in school and in home (Meng et al., 2019). Researchers obtained mixed results about the effect of using computer and technology on students' success (Agasisti et al., 2020; Chen & Wang, 2013; Eickelmann et al., 2016; Lei & Zhao, 2007; Liemb et al.,2014; Notten & Kraaykamp, 2009; Thiessen & Looker, 2007; Xin & Zhou, 2010). For example, Thiessen and Looker (2007) showed that intensive computer use in Canada was negative relationship with students' reading performance whereas Xin and Zhou (2010) showed that computer technology use increased students' performance. Using PISA 2012 data from 15 European countries, the study showed that intensive computer use in homework negatively affected test scores in all areas (Agasisti et al., 2020). It could be argued that the first studies about ICT in the literature were about the effect of computer or internet use on success in school and in home (Meng et al., 2019). These studies revealed the need for developing an ICT engagement construct. Later studies focused on development of construct related to ICT (De Wit et al., 2012; Janneck et al., 2013; Senkbeil & Ihme, 2017). Zylka et al. (2015) proposed a new ICT engagement scale which was more motivation and meta-cognition perspective of ICT related constructs. ICT engagement scale was adapted to the four-dimensional structure in PISA 2015. In recent studies, ICT engagement has been considered as a multidimensional construct and its effect on academic achievement has been explored. Different results were obtained (Cheema & Zhang, 2013; Hu et al., 2018; Lee & Wu, 2012; Luu & Freeman, 2011). For example, perceived ICT autonomy had a positive effect on achievement (Cheema & Zhang, 2013). According to the study conducted by Lee and Wu in 2012, interest in ICT and perceived ICT competence were positive predictors of reading achievement.

The ICT engagement scale, developed in PISA 2015 and used in PISA 2018, is a relatively new assessment tool. There were only two studies (Meng et al., 2019; Ma & Qin, 2021) exploring the validity of this scale across countries. It was necessary to explore the measurement invariance of this scale to make valid comparisons between different groups (Mâță et al., 2020). Measurement invariance is a property that indicates a measurement tool (a questionnaire in the case of survey research) measures the same concept in various subgroups in the same way (Davidov et al., 2014). The measurement issues of the newly ICT engagement scale need to be further explored. This research was devoted to explore the effects of ICT engagement factors on performance of science between Singapore and Turkey using Multi-group Structural Equation Modeling (Multi-group SEM) analysis. The first step was composed of the analyzes for configural, metric and scalar invariance of ICT engagement scale of PISA 2018 across Singapore and Turkey using Multi-group Confirmatory Factor Analysis (Multi-group CFA). As the ICT engagement scale provided acceptable invariant, effects of ICT engagement factors on students' science performance were compared between Singapore and Turkey in the second step.

Research Problem

In this research, Singapore and Turkey were chosen to compare. Students from these two countries completed the optional ICT engagement form in PISA 2018. These two countries represent different education systems and different success in PISA. Singapore education system can offer a customized curriculum for student groups created according to their technical and social characteristics in the same school, whereas Turkey education system offers the same curriculum for all students (Kilic Depren, 2020). Singapore and Turkey had different science performance in PISA 2018. According to PISA 2018 results, the average science performance of 15-year-olds in Turkey was 468 points and it was less than 489 points which was the average for OECD countries participating in the same cycle. Turkey's change in performance of science between PISA 2015 and 2018 indicated one of the strongest increases among participating countries and economies. In Singapore, whose average in science performance was one of the highest among countries and economies participating in PISA, the average score was 551 (OECD, 2019c). Singapore has national plans for ICT integration and implementation covering the educational environment and resources. Turkey's ICT policy also aims at improving both ICT infrastructure and capacity of stakeholders according to "Information Society and Action Plan (ISAP) for 2014-2018" prepared by The Ministry of Development (MoD) of Turkey. Considering that both countries are focused on the same goal in terms of ICT, Singapore, with the highest science achievement, and Turkey, with the highest increase in science performance between PISA 2015 and 2018, were selected to compare the effectiveness of ICT policy.

Research Focus

In this research, the measurement invariance of the ICT engagement scale was examined across Singapore and Turkey. If a sufficient degree of invariance is achieved (i.e., scalar invariance), then the effects of ICT engage-

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ment factors on performance of science could be compared across these two countries. Specifically, the following research questions were addressed:

1. To what extent does the ICT engagement scale show invariance across Singapore and Turkey? (Multi-group CFA)
2. If a sufficient level of invariance can be established, how do the effects of ICT engagement factors on student science performance differ by Singapore and Turkey? (Multi-group SEM)

Research Methodology

General Background

PISA evaluates to what extent 15-year-old students who are about to complete their compulsory education have acquired the knowledge and skills necessary for them to adapt to modern societies. This assessment examines the extent to which students can draw conclusions from the information they have acquired and to what extent they can apply this knowledge in school and out-of-school, rather than whether students can reproduce information. The PISA 2018 evaluation is the seventh since the program started in 1997. In the program, which is carried out and developed in cooperation between the governments of OECD countries and partner countries/economies, evaluations focusing on basic areas such as reading, mathematics and science are carried out in three-year cycles. The main assessment area in PISA 2018 was reading (Mathematics became the main field in 2003 and 2012, and science was the main field in 2006 and 2015) (OECD, 2019b).

Participants

The data were obtained from the PISA 2018 database which is open access and freely available. Missing values were excluded from the analysis. In Turkey 6531 students participated from 189 schools with 3396 being female 49.3% and 3494 being male 5.7%. In Singapore 6390 students from 166 schools were tested; 3277 were female 49.1 % and 3399 were male 5.9 %. A large part of the Singapore and Turkey data consisted of grade 10 students (respectively 91.3% and 77.8%).

Instrument and Procedures

Zylka et al. (2015) introduced ICT engagement scale as a motivation and meta-cognition of ICT literacy. First, the ICT engagement scale had a five-dimensional construct, and then it was revised to a four-dimensional construct. The revised ICT engagement scale has four factors: interest in ICT, perceived ICT competence, perceived autonomy in using ICT and social relatedness in using ICT. ICT engagement scale consists of 4 factors and 21 items in PISA 2018.

All items were measured by 4-point Likert scale. This scale ranged from 1 for strongly disagree to 4 for strongly agree (Zylka et al., 2015). Higher values of 4-point scale show better ICT engagement. The means of the items ranged from 2.16 to 3.17 and all were higher than the midpoint of the 4-point scale, 2.0. Descriptive statistics and internal consistency of the scale (Croanbach's alpha) are presented in Table 1. Cronbach's alpha coefficients of four factors for each of the two countries ranged from .846 to .876 and were sufficiently high.

Interest in ICT (IICT): IICT defines an individual's long-term choice about the tasks, topics, or activities related to ICT. Interest in ICT is expected to influence behavior related to ICT and produce positive emotions, learning and performance results (Goldhammer et al., 2016). In PISA 2018, this subscale had six items. Internal consistencies of interest in ICT were .792 for the Singapore data and .860 for Turkey data.

Perceived ICT competence (PICT): PICT is the belief of individuals about their knowledge with respect to ICT and to use this knowledge (Goldhammer et al., 2016). This subscale consisted of five items. Internal consistencies of perceived ICT competence were .806 for the Singapore data and .872 for Turkey data.

Perceived autonomy in using ICT (PAICT): PAICT projects the individual's perceived control and self-management in activities related to ICT (Goldhammer et al., 2016). It is expected to experience a sense of control over by using ICT tools and to associate their success in using these tools with their own abilities rather than other reasons (Kunina-Habenicht & Goldhammer, 2020). This subscale consisted of five items. Internal consistencies of perceived autonomy in using ICT were .867 for the Singapore data and .874 for Turkey data.

Social relatedness in using ICT (SRICT): It expresses the need for the individual to make ICT a subject in com-

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munication and interaction with others, and also to share their interest, knowledge, experience and activities with others (Goldhammer et al., 2016). This subscale consisted of five items. Internal consistencies of social relatedness in using ICT were .850 for the Singapore data and .868 for Turkey data.

Table 1
Descriptive Statistics and Reliabilities of ICT Engagement Constructs

	Singapore		Turkey		Overall	
	μ(*SD*)	α	μ(*SD*)	α	μ(*SD*)	α
IICT	3.14(0.68)	.792	2.82(0.44)	.860	2.98(0.56)	.846
PICT	2.95(0.80)	.806	2.80(0.56)	.872	2.87(0.68)	.846
PAICT	3.02(0.47)	.867	2.72(0.39)	.874	2.87(0.43)	.876
SRICT	2.69(0.06)	.850	2.72(0.04)	.868	2.70(0.05)	.859

Science Performance: Science literacy defined within the scope of PISA research is considered as the ability of students to deal with issues related to science and to reflect on scientific facts. Science literacy requires the ability to explain facts, design research methods, and interpret evaluation data and findings scientifically (OECD, 2019a). Science performance in PISA measures students' science literacy in the use of scientific knowledge to determine questions, gain new knowledge, describe scientific phenomena, and draw evidence-based conclusions about issues related to science. The science performances of 79 countries participating in PISA 2018 were evaluated over their average scores and results showed that the average science scores were varied between 59 and 336. Turkey, ranked 39 in science among 79 countries participating in PISA 2018, it ranked 30th among the 37 OECD countries (OECD, 2019d). Singapore was one of the top countries in science.

Measurement Invariance: Measurement invariance (MI) evaluates whether a construct is measured and interpreted in the same way across different groups and is a requirement for making valid comparisons (Putnick & Bornstein, 2016). CFA can be used within the scope of SEM to test measurement invariance. There are four hierarchical levels of MI in Multi-group CFA and each of these levels is based on the additional equality constraints on the model parameters if the previous invariance is met. Configural invariance, which is the first step of assessing measurement invariance, explores if the same items measure the same constructs across groups. Factor models belonging to all groups to be compared are estimated at the same time. Since this is the baseline model, the validity of the configural invariance is evaluated by the model fit measures. The configural model is a baseline model to compare with metric invariance (weak factorial invariance). After providing configural invariance, metric invariance is explored for whether factor loadings are equivalent across groups. Providing invariance of factor loadings shows that the construct has the same meaning across groups. After providing metric invariance, scalar invariance of item intercepts, is explored for metric invariant items. Scalar invariance (strong factorial invariance) indicates mean equivalence in different groups. After providing scalar invariance, the final step is to test residual invariance. The residual invariance (strict invariance) is required for full measurement invariance. The residual invariance is not required for testing mean differences. Since the residual invariance is insignificant for the interpretation of latent mean differences, this step can be skipped in many studies or if this step cannot be provided, latent factor means can be compared (Vandenberg & Lance, 2000).

Data Analysis

Mplus 6.1 and R Studio tools were used to analyze the data. First step, exploratory factor analysis (EFA) was applied to identify the structure of ICT engagement. After demonstrating the convergent validity and the discriminant validity, we used the Cronbach's alpha for assessing factor reliability.

Before investigating invariance, it is important to ensure that the ICT engagement model provides a good fit for both countries. Thus, the second step was to test whether the proposed four-factor ICT engagement construct fitted the data from each country using the single group CFA approach. In this step, the four-dimensional construct of ICT engagement was tried to confirm for both countries. The measurement models of ICT engagement were estimated via CFA using Maximum likelihood estimation (ML). Before conducting the CFA, the assumptions of

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normality were explored. The skewness values of the items varied between (-.92; -.14) and the kurtosis values of items varied between (-.76; .94). If the absolute values of skewness and kurtosis are below 1 deviation from normality is defined as slight, between 1 and 2.3, moderate, and above 2.3, severe. (Lei & Lomax, 2005). The absolute values of ICT engagement items skewness and kurtosis were below 1 the deviation from normality was weak so ML estimation was used in this research (Ooi et al., 2012; Şimşek & Tekeli, 2015). To evaluate the measurement model fit, three most common fit indices (Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA) and Standardized RMR (SRMR)) were used. CFI values more than .90 and RMSEA and SRMR values smaller than .08 indicate an acceptable model fit, whereas CFI values more than .95 and RMSEA and SRMR values smaller than .05 suggest good model fit (Hu & Bentler, 1999; Marsh et al., 2005)

After the ICT engagement construct was provided for each country, in the third step MI was tested using the multistage procedure of Multi-Group CFA. A configural model tested for whether the proposed structure of ICT engagement would be equal across the two groups. The configural model included the same number of factors and the same number of items. There was not equality restriction on measurement and structural parameters across countries. The Singapore and Turkey model were estimated at the same time. After the configural invariance was provided, the factor coefficients were kept equal for both groups to test metric invariance. The Likelihood-Ratio Test (LR) was used to evaluate the model fit in the measurement invariance analysis (Cheung & Rensvold, 2009). The change in CFI (ΔCFI) criterion which is less sensitive to the sample size and alternative fit indices (ΔRMSEA, ΔSRMR) were also considered. Chen (2007) suggested that such changes should be equal or less than .01 for the ΔCFI, .015 for the ΔRMSEA and .010 for the ΔSRMR. Metric invariance held, then, the scalar invariance model was examined. Factor loadings and item intercepts were kept equal in both countries. The results showed that scalar invariance model fit was acceptable. Thus, both the factor loadings and the item intercepts of ICT engagement scale were invariant across Singapore and Turkey. After scalar invariance held, residual invariance was examined. The residual invariance was not supported based on the chi-square difference test. As a result, we demonstrated scalar invariance of the scale with 4 factors and 21 items across the two countries; thus, we could proceed to structural invariance. When we explored the structural invariance, we only tested the factor mean invariance using the method that was recommended by Vandenberg and Lance (2000). Singapore was taken as the reference group when comparing factor means, so the estimated factor means for countries were actually the differences in factor means between groups. We demonstrated strong factorial invariance including configural invariance, metric invariance, and scalar invariance of ICT engagement model across groups, so we were able to use ICT engagement to meaningful and valid comparisons.

For the comparison of the effects of ICT engagement factors on performance of science between these two countries, we used the Multi-group SEM analysis in the fourth step. Before comparing the path coefficients across the countries, each of the two groups were modeled separately (Jiang et al., 2021). After that, the configural SEM model was explored considering the two groups simultaneously without any equality constraint on the structural path coefficients.

Research Results

Exploratory Factor Analysis (EFA)

First, EFA was performed on a total of 21 items to determine the factors. Kaiser-Meyer-Olkin (KMO), the measure of sampling adequacy should be greater than .5, KMO value was .934 which indicated the suitability for factor analysis. Bartlett's test of sphericity was rejected ($p< .001$). This demonstrated that there were appropriate correlations in the data for factor analysis. The EFA results using Principal Components Factoring with Promax rotation revealed four significant factors. The results showed that 63.50% of the total variance was explained by these four factors. Standardized factor loadings of 21 items are illustrated in Table 2.

As shown in Table 2, all the item loadings were perfect (Tabachnick & Fiddell, 2007). All the items were loaded stronger on the related factors than on the other factors and there were no items with noticeable cross-loads. Thus, convergent validity and discriminant validity were demonstrated (Churchill, 1979). The internal consistency of the factors was evaluated with Cronbach's alpha and they were found to be above the recommended threshold value of .60 (Hair et al., 1998). So, the scale was found to be reliable.

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Table 2
Standardized Factor Loadings and Cronbach's α

Factors	IICT	PICT	PAICT	SRICT
Standardized factor loadings	.658	.702	.831	.793
	.770	.811	.803	.820
	.787	.680	.778	.695
	.737	.864	.837	.862
	.728	.863	.831	.820
	.818			
Cronbach's α	.846	.846	.876	.859

Single group CFA

Table 3 shows the model fit indices of the overall data and each of the country for single group CFA. The results showed an acceptable fit for Singapore and the overall data. All the CFI values were greater than .90, all the RMSEA and SRMR were less than .08. For Turkey, the results showed a good fit. The CFA was .947 and the RMSEA and SRMR were less than .05. All the results showed that the four factor of ICT engagement scale was supported in both countries.

Table 3
Model Fit Indices of the CFA

	$\chi^2(df)$	RMSEA (90%-CI)	CFI	SRMR
Overall	15103.396 (400)	.075 (.074-.076)	.912	.079
Singapore	6967.367 (183)	.076 (.075-.078)	.911	.063
Turkey	4081.186 (183)	.057 (.056-.059)	.947	.034

Multi-group CFA

Table 4 represents the results of the Multi-group CFA. As shown in Table 4, configural model provided acceptable fit for the data (CFI=.92>.90, RMSEA=.053<.08 and SRMR=.062<.10) which indicated the construct equivalence of the ICT engagement across Singapore and Turkey. The metric model fit was found to be acceptable (CFI=.92>.90, RMSEA=.053<.08 and SRMR=.061<.10) and metric invariance was supported based on the chi-square difference test (c^2_{diff}=2682.127, Δdf=17, p>.001). In addition, ΔCFI≤.01, ΔRMSEA≤.015, and ΔSRMR≤.010 (Chen, 2007). So, the metric invariance indicated that the items were equivalently related to the latent factors. Furthermore, the scalar invariance model fit was found to be acceptable (CFI=.92>.90 RMSEA=.053<.08 and SRMR= .061<.10). We also conducted LR test with the current model ($\Delta\chi^2 = 16.840; \mathrm{df} = 18; \mathrm{p} = .5341$)$c^2_{diff}$ =1372.716, Δdf=17, p>.001) $\Delta\chi^2 = 10.273; \mathrm{df} = 18; \mathrm{p} = .9226$). and ΔCFI, ΔRMSEA and ΔSRMR indicated that scalar invariance was held. After scalar invariance provided, residual invariance was examined. The tests of differences in fit between residual invariance model and scalar model (c^2_{diff}=3$\Delta\chi^2$ =194,690; Δdf= 21, p<.001); $\mathrm{df} = 22; \mathrm{p} = .000$) indicated that residual invariance was not established.

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Table 4
Fit Indices for Invariance Tests of Measurement Model

Model	CFI	RMSEA	SRMR	$\Delta\chi^2(\Delta df)$	ΔCFI	Δ RMSEA	Δ SRMR
Configural Model	.91	.075	.079	-	-	-	-
Metric Model	.91	.070	.068	2682.127(17)	.00	-.005	-.011
Scalar Model	.92	.067	.051	1372.716 (17)	-.01	-.003	-.008
Residual Model	.90	. 062	.071	3194.690 (21)	-.02	.000	.020

Even if residual invariance cannot be achieved, groups can still be compared on the latent variable; strong factorial invariance is sufficient to make valid comparisons. Singapore was considered the reference group where all factor means were constrained to equal 0. Actually, estimated factor means were differences in factor means between Turkey and Singapore. The factor means invariance demonstrated that the factor means of interest in ICT (-.293, p<.001), perceived ICT competence (-.096, p<.001) and perceived autonomy in using ICT (-.326, p<.001) were significantly lower in Turkey than in Singapore while the factor mean (.042, p<.001) of social relatedness in using ICT was significantly higher in Turkey than in Singapore.

Multi-group SEM

We used Multi-group SEM to explore the equality or invariance of the path coefficients across the two countries. Before comparing the path coefficients across the countries, each of the two groups were modeled separately. The Singapore model was acceptable (RMSEA=.075, 90% CI=(.074, .077); SRMR =.064; CFI=.900). Interest in ICT (.178, p<.001) and perceived autonomy in using ICT (.208, p<.001) had positive effect on science performance. Perceived ICT competence (-.055, p<.01) and social interaction using ICT (-.305, p<.001) had negative effect on science performance. The Turkey model also was acceptable (RMSEA=.06, 90% CI= (.059, .062); SRMR=.037; CFI =.937). In the Turkey model, interest in ICT (.205, p<.001), perceived ICT competence (.185, p<.001) and perceived autonomy in using ICT (.063, p< .01) had significant positive effect on science performance. Social relatedness in using ICT (-.209, p<.001) had negative effect on science performance. Singapore and Turkey baseline SEM model fitted data very well.

To test the invariance of path coefficients, we estimated a configural SEM model for both Singapore and Turkey at the same time. The SEM model of the two groups, which was defined as a baseline model, showed an acceptable fit for the data (RMSEA =.062, 90% CI=(.061, .063); SRMR=.067; CFI = .900).

As the Multi-group SEM was supported, the direct effect of interest in ICT on science performance was restricted to be equal across the groups. The Wald test (c^2=14.654; df=1; p<.001) showed that the direct effect of interest in ICT on science performance was different for Singapore and Turkey. The direct effect of interest in ICT on science performance was lower in Singapore (.125, p<.001) than in Turkey (.248, p<.001). After that, the direct effect of perceived ICT competence on science performance was constrained to be equal across countries. Wald test (c^2= 37.938; df=1; p<.001) indicated that the direct effect of perceived ICT competence on science performance was non invariant for Singapore and Turkey. The direct effect of Perceived ICT competence on science performance was lower in Singapore (.055, p<.001) than in Turkey (.092, p<.001). Later, the direct effect of perceived autonomy in using ICT on science performance was constrained to be equal across the groups. Wald test (c^2= 51.826; df=1; p<.001) showed that the direct effect of perceived autonomy in using ICT on science performance was non invariant for Singapore and Turkey. The direct effect of perceived autonomy in using ICT on science performance was lower in Singapore (.088, p<.001) than in Turkey (.151, p<.001). After that, the direct effect of social relatedness in using ICT on science performance was set to equal across groups. Wald test (c^2= 63.334; df=1; p<.001) showed that the direct effect of social relatedness in using ICT on science performance was non invariant for Singapore and Turkey. The direct effect of social relatedness in using ICT on science performance was lower in Singapore (-.215, p<.001) than in Turkey (-.312, p<.001)

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Discussion

The aim of this research was to explore the effects of ICT engagement factors on science performance across Singapore and Turkey. The first step was to explore the measurement invariance of the ICT engagement scale across these two countries. The single group CFA results confirmed the four-dimensional structure of the ICT engagement scale. All items were loaded on the related factors of ICT engagement and all factors were reliable. The multi-group CFA results demonstrated that ICT engagement scale with 4 factors and 21 items had strong factorial invariance (configural, metric and scalar invariance) across these two countries. The ICT engagement had the same construct across Singapore and Turkey, so we were able to use ICT engagement to meaningful and valid comparisons. After the strong factorial invariance was confirmed, we tested factor mean invariance by treating Singapore as the reference group. The factor means invariance model showed that the factor means of interest in ICT, perceived ICT competence and perceived autonomy in using ICT were significantly lower in Turkey than in Singapore while the factor mean of social relatedness in using ICT was significantly higher in Turkey than in Singapore. According to the International Telecommunication Union (ITU) 2017 report, Singapore with a score of 8.05 had a higher ICT performance compared to Turkey with a score of 6.08. Singapore was at the top of this ranking, while Turkey was in the middle. Our results were parallel to levels of ICT development for these two countries except social relatedness in using ICT.

The multi group SEM results demonstrated that interest in ICT, perceived ICT competence and perceived autonomy in using ICT had positive direct effect on science performance and these effects were lower in Singapore than in Turkey. The social relatedness in using ICT had negative direct effect on science performance both in Singapore and in Turkey; this effect was lower in Singapore than in Turkey. The positive and significant effects of interest in ICT, perceived ICT competence and perceived autonomy in using ICT indicated that both Singapore and Turkey considered the role of ICT in education in a similar manner. These results were consistent for both countries, and they were compatible with the ICT policies. The negative effects of social relatedness on science performance emerged from the possible adverse side effect of ICT. These results were consistent with literature as expected. The higher effect for Turkey might be due to the fact that the students use ICT for social purposes rather than learning.

Students' interest in ICT showed significant positive effect on science performance both in Singapore and in Turkey. This result was also supported by previous studies showing that interest in ICT had a positive relationship with students' academic performance (Hu et al., 2018; Jansen et al., 2016; Lee & Wu, 2012; Meng et al., 2019; Xiao & Hu, 2019). Some of the studies showed that interest in ICT did not have significant effect on academic performance (Juhaňák et al., 2019), but most of these studies only analyzed a specific country. Students' interest in ICT was related to the pleasure and positive feelings of using products based to ICT such as mobile devices or computers (Zylka et al., 2015). According to the results of this research and other literature, students who are more interested in ICT use are likely to have better science learning outcomes. This can be explained as students who are more interested in ICT will participate in learning activities using computers or the internet more often than other students (Jansen et al., 2016; Lee & Wu, 2012). Also, these students will have a more motivated and positive attitude towards science learning with technology (Park & Weng, 2020). Students interested in ICT can learn science with an interactive educational software, training software or computer tutorial that are designed to help student learning. Students interested in ICT learn when and how they can use different tools and teachers can also inform students to use the right tools. For example, word processing software helps students for organizing ideas, writing homework and projects the works. Students can use spreadsheet for analyzing and modeling scientific data.

Students' perceived ICT competence also showed a significant positive effect on students' science performance both Singapore and Turkey. This result supported other studies' results (Hosein et al., 2010; Hu et al., 2018; Selwyn & Husen, 2010). Students with high perceived ICT competence can motivate themselves to solve more difficult issues with more effective strategies. According to these findings, students with high perceived ICT competence were more likely to use software or online resources to work than those with low ICT competencies (Hosein et al., 2010). However, some studies supported that ICT competence had no effect or it had negative relationship with performance (Juhaňák et al.2016; Xiao & Hu, 2019). The results varied depending on students' grade levels and which country was analyzed (Park & Weng, 2020). The competence in using ICT is considered an important skill that students need to acquire in order to be successful in the digital age.

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Students' perceived ICT autonomy had a significant positive effect on students' science performance both in Singapore and in Turkey. This result was consistent with the literature (Cárdenas-Claros & Oyanedel, 2016; Xiao & Hu, 2019; Meng et al., 2019). Autonomy implies that students can organize their learning and use ICT to complete tasks and achieve mastery (Fu, 2013). Students with higher autonomy in the use of ICT tend to take more control of their learning processes with technology. Moreover, when students realize that they can control their learning with ICT, they can strengthen their autonomy in using ICT and learn more by using ICT effectively (Serhan, 2009; Park & Weng, 2020). Considering the positive relationship between perceived ICT autonomy and students' science performance, it becomes necessary to organize the education system to support autonomy. Both parents and teachers can provide support to meet the autonomy needs of students. Teachers can direct students to science group work where they will use tools related to ICT and make them aware of their own achievements and shortcomings (Park & Weng, 2020).

Social relatedness in using ICT was significantly a negative effect on science performance both in Singapore and in Turkey, and its effect size was larger than ICT interest, competence, and autonomy. These obtained results were similar to some previous studies (Paul et al., 2012; Huang, 2018; Hu et al., 2018). For example, Hu et al. (2018) reported that students who used ICT for higher social interaction performed lower. Students who use social media too much have less time to learn (Englander et al., 2010). While using ICT for learning purposes, students may also lose their focus as they interact with other ICT-related activities such as games, chats, and social media alerts. Parents and teachers should alert students to the addiction of entertainment as well as motivate them to use ICT for learning purposes (Park & Weng, 2020).

Conclusions and Implications

In this research the relationship between ICT engagement factors and science performance was explored by Multi-group SEM across Turkey and Singapore based on the data for PISA 2018. These countries were selected for comparison purpose because they intended to use ICT in education indicated in their national plans. The success of Singapore in science performance was evident. So, it was the reference for comparison to the Turkey which gained fair improvement in recent PISA cycles. As a preliminary requirement of Multi-group SEM, the measurement invariance of ICT scale across these countries was provided hierarchically validating configural, metric, and scalar invariance. The Multi-group SEM result indicated that interest, perceived competence, and autonomy in ICT use showed a positive effect while social relatedness in using ICT had a negative effect on students' science performance both Singapore and Turkey. Although these effects were not different in their directions, their magnitudes were higher in Turkey than in Singapore.

This research contributes to the field of education both because it shows that the ICT engagement construct is comparable and because it shows the effect of four factors of ICT on science performance separately between these two countries. The results of this research can be a guide in educational policies to be determined to increase science performance and it will also be useful in positioning ICT in education system.

The positive effects of interest, perceived competence, and autonomy in ICT use on science performance can be regarded as an opportunity to the developing countries like Turkey considering the benefits of ICT in education. Turkey was in the middle rank of science performance according to PISA 2018 results, and it might be starting to appear in the positive results of these ICT policies implemented. The negative effect of social relatedness in using ICT on science performance should be handled by policy makers.

This research has a few limitations. First, the responses of students from Singapore and Turkey were analyzed. The results of this paper are limited to these selected countries. The research can be extended to different countries with different cultures and different educational structures. Second, the relationship between ICT engagement factors and science performance was explored. For future studies, the effect of ICT engagement factors on reading and mathematics performance can be explored. Third, in this research, only the comparison was made according to the countries, and no comparison was made by gender. It is planned to explore the measurement invariance of the ICT engagement scale according to gender.

Declaration of Interest

Authors declare no competing interest.

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THE EFFECT OF LEARNING EXPERIENCES ON INTEREST IN STEM CAREERS: A STRUCTURAL EQUATION MODEL

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Abstract. *Learning experiences can affect students' interest in STEM (science, technology, engineering, and mathematics) careers. Applying the social cognitive career theory, this study tested and compared the effect size and effect mechanism of formal learning experiences (FLE) and informal learning experiences (ILE) on 1133 tenth-grade students' interest in STEM careers (ISC) through a paper questionnaire survey. The results of structural equation model analysis showed that: 1) The total effect of ILE on students' ISC is much greater than that of FLE; 2) ILE, STEM self-efficacy (SSE) and STEM careers perceptions (SCP) can directly affect students' ISC; FLE and ILE can also indirectly affect students' ISC through the mediating role of SSE and SCP. The analyses suggest that in order to improve students' ISC, STEM education (especially informal STEM education) should be strengthened, both formal and informal education should pay attention to the cultivation of students' SSE and SCP.*

Keywords: *interest in STEM careers, learning experiences, social cognitive career theory, STEM careers perceptions, STEM self-efficacy, structural equation model*

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Introduction

In today's knowledge and technological era, science, technology, engineering, and mathematics (STEM) workers are the driving force behind economic progress of many economies. However, countries around the world are facing a shortage of STEM workers to varying degrees. For instance, the US Bureau of Labor Statistics (2017) predicted that the demand for STEM workers would grow by 1 million between 2012 and 2022. Despite the increase in demand, the number of students studying in STEM majors is declining (National Science Board, 2016). This disparity between demand and supply of skilled STEM graduates has led to a shortage of workers in the STEM field. The difficulty in filling job vacancies in the STEM field (Wyss et al., 2012) has resulted in an effort to improve the quantity and quality of STEM workers through reformation of the core goals of the current global education.

To encourage more students to pursue STEM majors and careers, development of interest in STEM careers is fundamental. Personal interest is the critical factor that affects one's career choice, especially in STEM fields (Bahar et al., 2016; Lloyd et al., 2018; Miller, et al., 2018; Nugent et al., 2015). Interest in STEM careers refers to personal pursuits and aspirations for STEM careers, which can predict students' inclinations to engage in STEM careers in the future to a large extent. However, as adolescents grow, they become less interested in STEM careers (Chachashvili-Bolotin et al., 2019; Osborne et al., 2003), and their aspirations for STEM careers fades. The 2015 Programme for International Student Assessment (PISA) reported that the proportion of Chinese 15-year-old students who are willing to pursue STEM-related careers in the future is relatively low, far below the average level of the OECD (OECD, 2016a). Research (Lindahl, 2007) has shown that the best time to cultivate adolescents' interest in STEM careers is before the age of 13-14. Therefore, understanding how interest in STEM careers can be cultivated among adolescents could be one way to enhance the number and quality of individuals for the STEM workforce.

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Earlier studies (Archer et al., 2012; Dewitt 2013; Mohtar et al., 2019) conducted to understand interest in STEM careers (ISC) have revealed that factors such as gender, school, society, media, scientific capital and personality characteristics exert profound effects on ISC. Comparatively, there are fewer studies relating formal learning experiences (FLE) and informal learning experiences (ILE) to students' ISC (Maiorca et al., 2021; Mohr-Schroeder et al., 2014; Roberts et al., 2018). Further, the foci of current studies have not compared the effects between FLE and ILE on ISC and centered on university students' experiences with little attention paid to high school students although it has been shown that intention to pursue STEM careers could start in high school (Bottia et al., 2015). Consequently, this study was carried out to focus on the effects of FLE and ILE on ISC among tenth-grade students, so as to provide theoretical reference for relevant policy makers and educators to cultivate students' ISC. The research questions guiding this study were: 1) Whether FLE and ILE can affect ISC? If so, which has greater effect? 2) What is the effect mechanism of FLE and ILE on students' ISC?

Literature Review

Based on Bandura's Social Cognitive Theory, the Social Cognitive Career Theory (SCCT) was proposed by Lent et al. (1994). This theory integrates external factors such as learning experiences and personal cognitive factors (such as self-efficacy, outcome expectation and career interest) dynamically to reveal the process of career choice. The SCCT is one of the most powerful theories to explain career choice at present. As such, the literature review was based on the three major components of SCCT that have significant effects on ISC: 1) learning experiences, 2) STEM self-efficacy, and 3) STEM careers perceptions.

Learning Experiences (LE)

STEM Learning experiences (whether formal or informal) have effects on students' ISC. Formal learning experiences (FLE) mainly refer to the learning experiences through school organization, classroom teaching and other formal learning institutions (Eshach, 2007). FLE are usually regulated by the state, planned with clear goals and curriculum knowledge system, and realized by relying on standardized learning materials. FLE include professional information provided by teachers, teacher support, teaching methods, courses and teaching environment, etc. Rowan-Kenyon et al. (2011) have pointed out that careers information and careers projects have significant effects on adolescents' career planning. STEM curriculum and classroom environment have important impacts on students' interest in STEM (Maltese et al., 2011; Wieselmann et al., 2020). Adding research projects and cooperative inquiry activities to STEM courses is conducive to enhancing students' ISC (Hampden et al., 2013; Kang et al., 2017). Teaching strategies (such as student-centered teaching, project-based learning, and inquiry-based teaching) can also affect students' ISC (Lou et al., 2011; Wyss et al., 2012; Zhou et al., 2019). As such, with deliberate structures and intentions to engage students with inquiry ways of learning, formal education can be designed to affect students' STEM self-efficacy and STEM careers perceptions, as well as their ISC (Mohtar et al., 2019; Wang et al., 2020).

Compared with FLE, informal learning experiences (ILE) refer to the learning experiences of acquiring new knowledge and skills outside the classroom, in informal occasions such as work, life and society. The sphere of informal learning includes visiting science and technology museums, other museums and science centers, participating in various STEM competitions and summer camps (Eshach, 2007). Numerous studies (Halim et al., 2018; Kitchen et al., 2018; Melchior et al., 2018; Miller et al., 2018) have shown that informal STEM learning can affect students' ISC. Students who participate in informal STEM-related programs and STEM competitions are more interested in STEM careers than those who do not participate, and the effect can be increased by three times if students participate in more than one competition (Miller et al., 2018). STEM projects outside the classroom can affect students' choice of STEM-related subjects and college majors (Melchior et al., 2018). Students participating in summer STEM programs are 1.4 times more likely to pursue a STEM career than other ones (Kitchen et al., 2018). ILE related to STEM also improve students' STEM self-efficacy and STEM careers perceptions (Halim et al., 2018).

STEM Self-efficacy (SSE)

Similar to learning experiences, SSE has an important impact on ISC. Self-efficacy was proposed by Bandura (1977) and it refers to a personal subjective judgment or confidence in one's ability to engage in a certain posi-

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tion or complete a certain task. Self-efficacy can predict a person's career interest to a large extent, and students are more likely to be interested in careers that they have better abilities and performance, and less likely to be attracted to careers that they are not confident in. This is supported by theory-based models, such as SCCT (Lent, 1994). Many studies (Halim et al., 2018; Maiorca et al., 2021; Mohtar et al., 2019; Nugent et al., 2015; Wang et al., 2020) have demonstrated that SSE is an important factor for individuals to pursue STEM careers. In this study, SSE was assessed by students' confidence in their own abilities and performance in the four subjects of STEM (Mohtar et al., 2019).

STEM Careers Perceptions (SCP)

Another factor that has effect on ISC is SCP. SCP refer to students' understanding and knowledge of STEM career prospects, skills required and self-development (Franz-Odendaal et al., 2016; Mohtar et al., 2019; Wyss et al., 2012). Recent studies have found that SSE and SCP are important factors in predicting whether adolescents are interested in STEM careers (Mohtar et al., 2019; Nugent et al., 2015; Schumacher et al., 2009; Wyss et al., 2012; Mohr-Schroeder et al., 2014; Kitchen et al., 2018). Research by Wyss et al. (2012) has shown that students may not be interested in STEM careers if the relevant information about skills, qualifications, requirements and employment prospects are not clearly presented to them. As such, the low ISC could be due to the fact that most schools do not introduce information about STEM careers to students. Informal STEM learning experiences can positively influence students' STEM careers perceptions and enhance their ISC (Kitchen et al., 2018; Mohr-Schroeder et al., 2014).

Research Hypothesis

SCCT is a theory with the most explanatory power for career choice at present. There are a large number of studies (Bahar et al., 2016; Kang et al., 2017; Kier et al., 2014; Maiorca et al., 2021; Mothar et al., 2019; Nugent et al., 2015) applying SCCT to study students' interests in STEM careers and career aspirations. According to SCCT, positive environmental factors (such as learning experiences) can improve students' self-efficacy and outcome expectation of careers, deepen students' perceptions of related careers, and thus enhance students' interest and aspirations for related careers. In this study, the outcome expectations of STEM careers are measured by SCP (Mothar et al., 2019). Based on the theoretical constructs of SCCT and the literature reviewed, ISC is affected by FLE, ILE, SSE, and SCP, so this study proposed the following four direct hypotheses ($H_1 \sim H_4$).

H_1: FLE can directly and positively affect students' ISC.

H_2: ILE can directly and positively affect students' ISC.

H_3: SSE can directly and positively affect students' ISC.

H_4: SCP can directly and positively affect students' ISC.

In SCCT, positive learning experiences can improve self-efficacy and outcome expectation, and individuals with high self-efficacy also have high outcome expectation for specific careers. Self-efficacy and outcome expectation play key roles in the formation of careers interest, both of which are the basis of the development of careers interest. In other words, self-efficacy and outcome expectation play important mediating roles in the effects of learning experiences on careers interest. Based on the above analysis, this study assumed that SSE and SCP play mediating roles between LE and ISC and proposed the following six mediating hypotheses ($H_5 \sim H_{10}$).

H_5: SSE play a mediating role between FLE and ISC.

H_6: SCP play a mediating role between FLE and ISC.

H_7: SSE and SCP play a chain mediating role between FLE and ISC.

H_8: SSE play a mediating role between ILE and ISC.

H_9: SCP play a mediating role between ILE and ISC.

H_{10}: SSE and SCP play a chain mediating role between ILE and ISC.

In order to explore the effect mechanism of FLE and ILE on ISC, a total of 10 hypotheses were proposed, and the hypothesis model (Figure 1) was constructed based on SCCT to test: 1) Whether FLE, ILE, SSE, and SCP can affect ISC? 2) Do SSE and SCP play mediating roles between LE and ISC?

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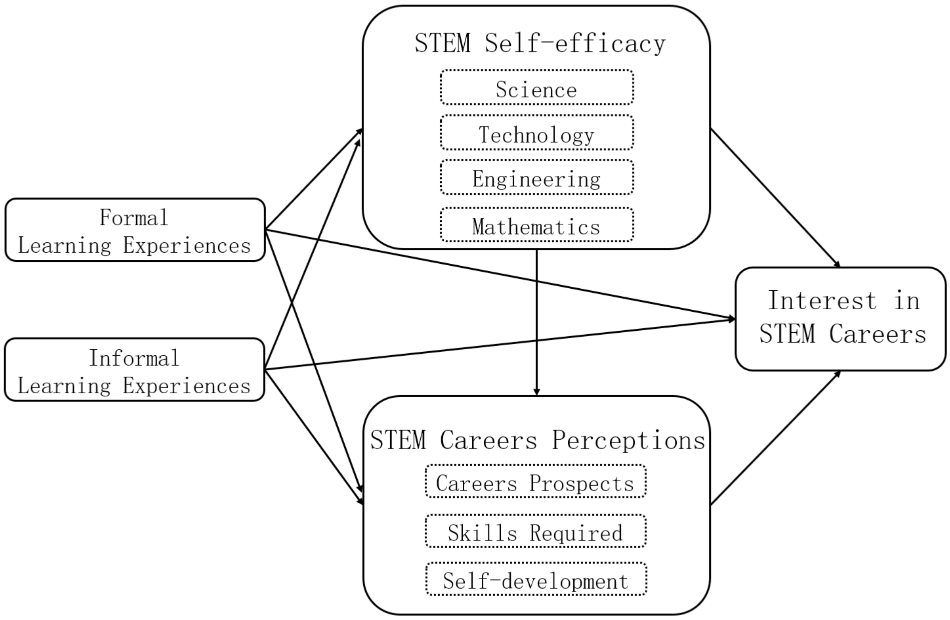
Figure 1
Hypothesis Model of the Effect of Learning Experiences on Interest in STEM Careers



Research Methodology

General Background

Based on the SCCT as the framework, five constructs of this study were FLE, ILE, SSE, SCP and ISC. The final questionnaire was obtained through the revision of several well-known international questionnaires related to interest in STEM careers (Archer et al., 2013; Buday et al., 2012; Kier et al., 2014; Mohtar et al., 2019; Nugent et al., 2015) and the test of their reliability and validity. The paper questionnaire survey was conducted among tenth-grade students in Hunan Province, China from September to December 2020, and the data were analyzed through structural equation modeling to explore the effect mechanism of FLE and ILE on ISC among high school students.

Sample

This research selected the tenth-grade students in Hunan Province, China who sat for the new college entrance examination in September 2020. The considerations for the selection of the sample were: 1) Under the new college entrance examination format, tenth-grade students have to make choices of courses, subjects and examinations, etc. As such, they are in the position to make independent judgments of their career interest. 2) Tenth-grade students are relatively mature in physical and mental development, so they are able to accurately assess the effects of LE on themselves. 3) Compared with students in Grade 11 and Grade 12, students in Grade 10 have less study pressure and have enough time to answer the questionnaire carefully. 4) An early intervention at lower grades is more beneficial hence tenth-grade students were chosen. Considering the different levels of economic developments in different regions, this study adopted multi-level random sampling method to select tenth-grade students in Changsha, Changde, and Xiangxi Autonomous Prefecture of Hunan Province, China to conduct on-site questionnaire surveys. Hair et al. (2014) suggested that the sample size should be at least 10 times the number of variables. As there were 40 variables in this study, at least 400 samples were needed. In addition, Comrey and Lee (1992) considered that a sample size greater than 1000 is the best, so a total of 1240 paper questionnaires were collected finally in this study. After inspection, 107 invalid questionnaires (missing answers and random answers) were eliminated. In total 1133 valid questionnaires were obtained, and this worked out to an effective rate of 91.37%. Among them, 549 were boys, accounting for 48.5%, and 584 were girls, accounting for 51.5%. There were 383 in

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provincial-level demonstration senior high schools, accounting for 33.8%, 369 in municipal-level demonstration senior high schools, accounting for 32.6%, 381 in general senior high schools, accounting for 33.6%.

Procedures

In order to protect the privacy of participants, after obtaining the consent of the head teacher and the students, an anonymous questionnaire survey was administered on a class basis. Each class was equipped with one or two graduate students majoring in science education as the main tester, who explained the instructions and requirements for the participants. The participants filled in the questionnaires within the specified time (about 20 minutes) and the questionnaires were collected on site after completion.

Instrument

The questionnaire was divided into five parts: FLE, ILE, SSE, SCP and ISC (Table 1). All items were measured using the 5-point Likert scale, from "strongly disagree" to "strongly agree". The higher the score, the greater the degree of agreement. Among the constructs, the FLE, ILE and SCP parts were adapted from the instrument developed by Mohtar et al. (2019). The SSE part was adapted from the instruments developed by Buday et al. (2012), Kier et al. (2014) and Nugent et al. (2015). The ISC part was adapted from the instrument developed by ASPIRES Project Group, King's College London, UK (Archer et al. 2013). Combining the suggestions of two experts engaged in science education, one expert engaged in educational statistics, and three front-line teachers, and after two expert meetings, an exploratory factor analysis (EFA) was conducted on all items. The EFA showed that the Kaiser-Meyer-Olkin (*KMO*) is .914, and the value of Bartlett's test of sphericity is 12687 (df=171, p<.001), meeting the judgement standards (*KMO*>.70, p<.05) proposed by Howard (2016). After deleting items with unobvious factor loading, the item factor loading of each construct is between .594 and .887, indicating that the structure of the questionnaire was well divided. As shown in Table 1, among all the constructs, SSE and SCP include four and three sub-constructs respectively, and the score of each sub-construct was calculated by the average score of the items it includes. For example, the three sub-constructs of SCP are "Careers Prospects", "Skills required", "Self-development". Each sub-construct of SCP contains three items, and the score of each sub-construct was calculated by the average score of the three items.

Table 1
Constructs of the Questionnaire

Construct	Sub-construct	Number of Items	Examples of Item
Demographic variables		3	School, Gender, Grade
FLE		4	In class, teacher introduce STEM careers to us.
ILE		4	I have participated in STEM-related competitions.
SSE	Science	4	I can carry out scientific experiments properly.
	Technology	4	I can use everyday technological products easily.
	Engineering	4	I can repair a broken toy.
	Mathematics	4	I can draw a graph from the provided data.
SCP	Careers Prospects	3	Those in STEM fields can get jobs easily.
	Skills required	3	STEM careers require creative problem-solving skills.
	Self-development	3	STEM careers contribute to self-development.
ISC		4	I will pursue a STEM career in the future.
Total		40	

The reliability and validity of the questionnaire are shown in Table 2. First of all, the overall Cronbach's α reliability coefficient of the questionnaire is .916, and the Cronbach's α of each part "FLE", "ILE", "SSE", "SCP", and "ISC" are .824, .811, .832, .834, .928 respectively, indicating that the questionnaire has high internal consistency and high

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reliability. Second, confirmatory factor analysis (CFA) was used to test the validity. The results showed that all the standardized factor loadings are between .559 and .935, which reach the standard of 0.5 to 0.95 and the significance level, indicating that all the items and constructs are effective. The composite reliability (*CR*)>0.8 and the average variance extracted (*AVE*)>0.5, indicating each construct has high convergent validity. The correlation coefficients between the constructs are less than the square root of *AVE* in each construct, indicating that the questionnaire has good discriminant validity. From the fitting index, RMSEA=.063<.08, SRMR=.043<.08, and all other goodness-of-fit indexes are greater than 0.9, indicating that the data fit well.

Table 2
Reliability and Validity of the Questionnaire

Construct	Item	Factor Loading	Cronbach's α	CR	AVE	FLE	ILE	SSE	SCP	ISC
FLE	FLE1	.760	.824	.825	.542	.736				
	FLE2	.775								
	FLE3	.665								
	FLE4	.741								
ILE	ILE1	.754	.811	.817	.528	.700	.726			
	ILE2	.728								
	ILE3	.721								
	ILE4	.702								
SSE	Science	.833	.832	.836	.567	.708	.695	.753		
	Technology	.559								
	Engineering	.697								
	Mathematics	.880								
SCP	Prospects	.623	.834	.841	.643	.410	.367	.479	.802	
	Skills	.853								
	Development	.901								
ISC	ISC1	.916	.928	.929	.767	.432	.548	.507	.507	.876
	ISC2	.935								
	ISC3	.813								
	ISC4	.833								

Data Analysis

Firstly, the analysis of reliability and validity was carried out by the following methods. Cronbach's *α* was used to analyze the reliability of the whole questionnaire and each construct. The content validity of the questionnaire was established through consultation with relevant experts engaged in science education and educational statistics. The structural validity and convergence validity were tested through EFA and CFA, and the discriminant validity was tested by judging whether the correlation coefficient between dimensions was less than the square root of *AVE* of the construct. Secondly, the Harman single factor test (Podsakoff et al., 2003) was performed to ensure that there was no serious common method deviation in this study. The structural equation model was constructed, and the fitting degree of the model was judged by the goodness of fit indexes. The *p*-value was used to determine whether the direct effects of FLE, ILE, SSE, and SCP on ISC were significant, and the sizes of the effects were analyzed by the standardized path coefficients(*β*). Finally, whether the 95% confidence interval of Bootstrap mediation test (Preacher & Hayes, 2004) included 0 was used to test whether the indirect effects of FLE and ILE on ISC were significant and the size of the total effect. All the above analyses were performed in SPSS23.0 and AMOS23.0.

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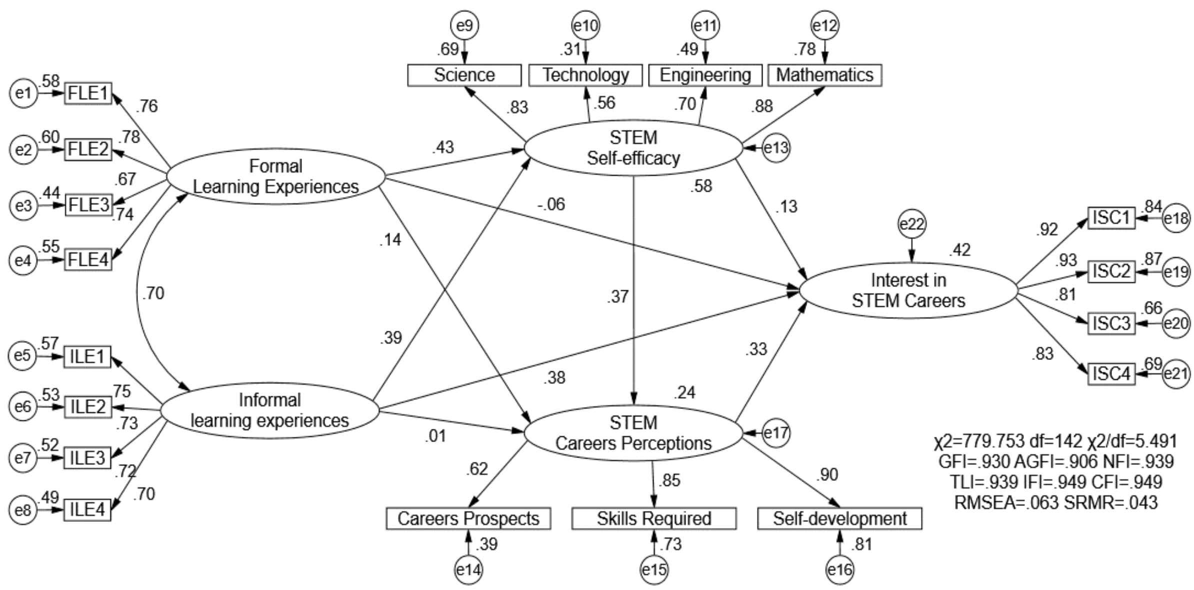
Research Results

Harman single factor test was used to test the data for common method deviation (Podsakoff et al., 2003). The results showed that there are five factors with eigenvalues greater than 1, which account for 72.12% of the variation, and the explanation rate of the maximum factor variance is 40.54%, which is less than the 50% judgment standard recommended by Hair et al. (2014). Therefore, there is no serious common method bias in this study.

The “Structural Equation Model of The Effect of Learning Experiences on Interest in STEM Careers” was constructed in AMOS23.0 (Figure 2), which shows all path coefficients, factor loadings, residual values, etc. of the model using the maximum likelihood method. The standardized factor loadings of all observed variables are between 0.56 and 0.93, which reach the test standard of 0.5 to 0.95. All residual values are positive, indicating that the model definition is reasonable. The lower right part of Figure 2 shows the fit of the model. In the structural equation model, when the sample size is greater than 200, it is easy to cause the chi-square value of the model to expand, resulting in poor model fit (Bollen & Stine, 1993). Therefore, it is recommended to use other goodness-of-fit indexes to evaluate the model (Bentler, 1990). Although the χ^2/df=5.491 of the model is slightly higher than the standard value of 5 due to the large sample size, other fitting indicators are at a good level, RMSEA=.063 (<.08, indicating a good fit), SRMR=.043 (<.08, indicating good fit), and all other goodness-of-fit indexes are greater than 0.9 (GFI=.930, AGFI=.906, NFI=.939, TLI=.939, IFI=.949, CFI=.949). These showed that the constructed model better demonstrates the effect mechanism of FLE and ILE on high school students’ ISC, which is suitable for further exploring the relationship between variables. Figure 2 also shows the direct standardized path coefficients between the variables.

Figure 2

The Structural Equation Model of the Effect of Learning Experiences on Interest in STEM Careers



The significance test of the direct effects between each variable is shown in Table 3. The direct effect of FLE on ISC is not significant (β=-.061, p>.05), indicating hypothesis H_1 is not supported; the direct effect of ILE on ISC is significant (β=.382, p<.001), indicating hypothesis H_2 is supported; the direct effect of SSE on ISC is significant (β=.127, p<.05), indicating hypothesis H_3 is supported; the direct effect of SCP on ISC is significant (β=.331, p<.001), indicating hypothesis H_4 is supported. From the perspective of effect size, ILE> SCP> SSE. FLE have no significant direct effect on ISC, but they may indirectly affect the ISC among high school students by affecting SSE and SCP.

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Table 3
The Direct Effects Test of the Model

Hypothesis	*β*	*S.E.*	*t*	*p*	Supported /Not supported
H_1: FLE→ ISC	-.061	.072	-1.212	.226	Not supported
H_2: ILE → ISC	.382	.072	7.368	***	Supported
H_3: SSE → ISC	.127	.066	2.559	.010**	Supported
H_4: SCP → ISC	.331	.072	9.073	***	Supported

Note: ****p*<.001; ***p*<.01; **p*<.05.

In order to test whether the indirect effects of learning experiences (FLE and ILE) on interest in STEM careers are significant, the Bootstrap mediating effect test method (Preacher & Hayes, 2004) was adopted to repeat the sampling 5000 times and calculate the 95% confidence interval (CI). If the 95% CI does not include 0, the mediation effect of the path is significant. Table 4 shows the direct effect, indirect effect, indirect total effect, total effect, and the difference between the total effects of FLE and ILE on ISC. The 95% confidence interval of the mediating effect (β=.055) of H_5 (FLE→ SSE→ ISC) is [.009, .108], which does not contain 0, so H_5 is supported; The 95% confidence interval of the mediating effect (β=.046) of H_6 (FLE→ SCP→ ISC) is [.005, .092], which does not contain 0, so H_6 is supported; The 95% confidence interval of the mediating effect (β=.054) of H_7 (FLE→ SSE→ SCP→ ISC) is [.033,.082], which does not contain 0, so H_7 is supported. These showed that FLE can affect ISC through parallel mediation and chain mediation of SSE and SCP. The indirect total effect of FLE on ISC is significant (β=.155, p<.01) and the direct effect of FLE on ISC is not significant (β=-.061, p=.226>.05), so the effect of FLE on ISC is completely mediated by SSE and SCP. The 95% confidence interval of the mediating effect (β=.049) of H_8 (ILE→ SSE→ ISC) is [.008, .091], which does not contain 0, so H_8 is supported; The 95% confidence interval of the mediating effect (β=.003) of H_9 (ILE→ SCP→ ISC) is [-.033, .039] which contains 0, so H_9 is not supported; The 95% confidence interval of the mediating effect (β=.048) of H_{10} (ILE→ SSE→ SCP→ ISC) is [.029, .074], which does not contain 0, so H_{10} is supported. The total indirect effect of ILE on ISC is significant (β=.101, p<.01), and the direct effect of ILE on ISC is also significant (β=.382, p<.001), therefore, the effect of ILE on ISC is partially mediated by SSE and SCP. Overall, the total effect of ILE (β=.483, p<.001) on ISC is much greater than that of FLE (β=.155, p<.01), and the difference between their effect size is significant (β=.328, p<.001), indicating that the total effect of ILE on ISC is much greater than that of FLE.

Table 4
The Indirect Effects Test of the Model

Path	Direct effect			Indirect effect					Total effect		
						Bootstrap 95% *CI*					
	β	*S.E.*	*p*	*β*	*S.E.*	*Lower*	*Upper*	*p*	*β*	*S.E.*	*p*
FLE→ISC	-.061	.072	.226								
H_5: FLE→SSE→ISC				.055	.026	.009	.108	.022*			
H_6: FLE→SCP→ISC				.046	.022	.005	.092	.029*			
H_7: FLE→SSE→SCP→ISC				.054	.012	.033	.082	***			
Indirect total effect of FLE				.155	.033	.092	.221	.001**			

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Path	Direct effect			Indirect effect					Total effect		
						Bootstrap 95% *CI*					
	β	*S.E.*	*p*	*β*	*S.E.*	Lower	Upper	*p*	*β*	*S.E.*	*p*
Total effect of FLE									.155	.033	.001**
ILE→ISC	.382	.072	***								
H_8: ILE→SSE→ISC				.049	.021	.008	.091	.023*			
H_9: ILE→SCP→ISC				.003	.018	-.033	.039	.847			
H_{10}: ILE→SSE→SCP→ISC				.048	.012	.029	.074	***			
Indirect total effect of ILE				.101	.026	.051	.154	.001**			
Total effect of ILE									.483	.049	***
Difference									.328	.067	***

Note: ***p<.001, **p<.01, *p<.05; Difference="Total effect of ILE" - "Total effect of FLE".

Discussion

Based on the framework of SCCT, this research explored the effect size and effect mechanism of LE (FLE and ILE) on high school students' ISC. The results showed that ILE, SSE and SCP can directly and positively affect students' ISC, and FLE and ILE can also indirectly affect students' ISC through the mediating roles of SSE and SCP.

From the results of direct effects, ILE, SSE and SCP significantly affect students' ISC, which is consistent with SCCT and the results of related studies. First of all, this study found that ILE, such as visiting STEM related museums, participating in STEM related clubs, competitions and summer camps can promote ISC significantly, which is consistent with previous research results (Kitchen et al., 2018; Maiorca et al., 2021; Nugent et al., 2015). Secondly, students with higher STEM self-efficacy are more confident that they have the ability to engage in STEM careers and achieve good results, and thus more interested in STEM careers (Mohtar et al., 2019; Wang et al., 2020). Thirdly, the clearer the knowledge about STEM career prospects, skills required, and self-development, the more likely students are to make sober and wise decisions. SCP is an important factor for adolescents to be interested in STEM careers (Kitchen et al., 2018; Mohr-Schroeder et al., 2014; Mohtar et al., 2019; Nugent et al., 2015; Schumacher et al., 2009; Wyss et al., 2012). However, the direct effect of FLE on ISC is not significant, and the study of Zhou et al. (2019) also proved this conclusion that the typical school system fails to improve students' ISC. The reason may be that although teachers are encouraged to conduct inquiry-based teaching, problem-based and project-based learning (PBL) during classroom instruction, due to the impact of class hours and examination evaluation, teachers paid more attention to the imparting of knowledge in class, rather than the cultivation of students' ISC.

From the results of indirect effects, LE (FLE and ILE) can indirectly and positively affect ISC through the mediating role of SSE and SCP. This is consistent with SCCT, and further expands the application scope of SCCT. In other words, SCCT is suitable for research on students' ISC. Although in many studies (Kitchen et al., 2018; Maiorca et al., 2021; Schroeder et al., 2014), LE have important effects on students' ISC, few studies have found and proved the indirect effects of LE. Positive LE (FLE and ILE) can enhance students' SSE and promote their understanding and awareness of STEM careers, which in turn increase their ISC. However, this study also found that ILE could not affect ISC through SCP, mainly because the first half of the mediation (the effect of ILE on SCP) is not significant. The reason may be that current informal STEM education does not focus on students' understanding and awareness of STEM careers, or it may be that these STEM learning activities are not related to real STEM careers. This suggest that STEM activities and programs in schools should have similar characteristics, methods and basic principles to the work performed by professionals in STEM field (Kitchen et al., 2018). As such, both formal education and informal education, educators should adopt appropriate teaching strategies

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and teaching activities, cultivate a good teacher-student relationship, stimulate students' learning initiative, optimize students' STEM learning experiences, so as to more effectively enhance the students' SSE and SCP, and then develop their ISC.

In terms of the total effect, the effect of ILE on ISC is much greater than that of FLE. This finding is significant because few studies have compared the effects of FLE and ILE on ISC, which also provides inspirations for us to put forward related strategies. First of all, informal STEM education should be strongly encouraged and promoted, especially in the high school stage, because it has been shown that students' intention to pursue STEM careers could start at this stage (Bottia et al., 2015). Thus, educators and policy makers could strengthen collaboration between colleges and high schools to develop effective STEM activities that are relevant to real STEM careers; The training of STEM teachers (including pre-service and post-service training) should be strengthened, so that STEM programs can be carried out successfully; Parents should strongly support their children's participation in STEM-related competitions, clubs, camps, and museums. Secondly, if students who are limited by objective factors such as the economic and educational level of the area and the socioeconomic status of the family cannot get access to informal STEM education, the following formal education measures should be adopted to enhance students' ISC although informal STEM education has a greater effect on students' ISC than formal education. This study showed that more scientific experiments, collaborative inquiry activities and PBL in classroom instruction are conducive to improving students' ISC, and some studies (Hampden et al., 2013; Kang et al., 2017; Zhou et al., 2019) also proved this conclusion. Therefore, inquiry teaching and PBL should be adopted in formal education, and the competence and literacy of teachers in STEM-related disciplines (mathematics, physics, chemistry, biology, geography, technology, etc.) should be improved. In addition, ISC could also be raised in formal education by strengthening students' STEM careers perceptions. However, schools offer limited information on STEM careers and textbooks feature limited range of STEM careers, especially in primary school science textbooks. Therefore, it is necessary to enrich the career education environment and further explore how to integrate the introductions of STEM careers into textbooks. At the same time, the interview videos of STEM professionals could also be incorporated and synchronized into corresponding courses. For example, when students are learning DNA, they can watch a video of interviews with genetic counselors.

Conclusions and Future Research

Referring to the two research questions that "Whether FLE and ILE can affect ISC? If so, which have greater effect?" and "What is the effect mechanism of FLE and ILE on students' ISC?", the results showed that: 1) FLE and ILE can positively affect students' ISC and the total effect of ILE on students' ISC is much greater than that of FLE; 2) ILE, SSE and SCP can directly and positively affect students' ISC, and LE (FLE and ILE) can indirectly and positively affect ISC through the mediating roles of SSE and SCP. Based on the quantitative analysis through structural equation modeling, it has been confirmed that ILE play a greater role in promoting students' ISC, and the effect mechanism model of LE (FLE and ILE) on ISC has been established.

In order to improve students' ISC, STEM education (especially informal STEM education) should be strengthened. First of all, informal STEM education should be strongly encouraged and promoted. Relevant departments should develop effective informal STEM activities, teachers should ensure the implementation of informal STEM education, and parents should support children to participate in informal STEM activities. Secondly, in formal education, teachers should try to adopt inquiry-based teaching and PBL, enrich the career education environment and explore how to integrate STEM career introductions into textbooks and courses. Finally, both formal and informal education should pay attention to the cultivation of students' STEM self-efficacy and STEM careers perception in the process. Although this research was carried out in the context of Chinese high school education, measures to improve high school students' interest in STEM careers may have implications for other countries as educational issues faced by different countries have some significant similarities, especially the issues of low interest in STEM careers among high school students. The conclusions of this study could provide some useful references to the teachers and policy makers in STEM, particularly those who are designing STEM learning experiences. The stakeholders (e.g., students, parents, teachers, policy makers, schools, private sector, etc.) should realize the critical role of informal education in fostering students' interest in STEM careers, and encourage them to form a STEM education community, to participate in, support, and develop informal STEM programs.

Based on the results of the study, future research could consider interviews on top of the questionnaire to triangulate the findings. Further, longitudinal research (from primary school to university) could be carried

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out on the longevity and intensity of adolescents' interest in STEM careers and how it changes. Previous studies have found significant differences in students' interest in STEM careers in terms of gender, and the formation mechanism of interest in STEM careers of different groups is different. As such, in-depth studies can be conducted to compare across groups of learners from different genders. Finally, based on different economic and cultural backgrounds, how informal STEM programs should be designed to cater to the needs of different student groups.

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Declaration of Interest

Authors declare no competing interest.

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EXPLORING THE EFFECTS ON FIFTH GRADERS' CONCEPT ACHIEVEMENT AND SCIENTIFIC EPISTEMOLOGICAL BELIEFS: APPLYING THE PREDICTION-OBSERVATION-EXPLANATION INQUIRY-BASED LEARNING MODEL IN SCIENCE EDUCATION

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Kai-Hsin Tai,
Jon-Chao Hong

Abstract. *The inquiry-based learning model can facilitate students' understanding of scientific concepts. Scientific epistemological beliefs (SEBs) are related to students' beliefs about the nature of the process of knowledge in science education. However, whether the "prediction-observation-explanation" (POE) inquiry-based learning model can facilitate fifth graders' concept achievement and SEBs in science education has not been extensively studied. This study selected the unit of Light Refraction to explore the effects of POE learning on fifth graders' science concept achievement and SEBs. The Light Refraction Test and Scientific Epistemological Beliefs measurement were applied to the two groups prior to and following the experiment. The experimental group (N=86) participated in POE inquiry-based learning, whereas the control group (N=88) participated without POE inquiry-based learning. The results revealed a significant difference between the two groups, with the experimental group learners performing better than the control group in the concept achievement. In addition, the results showed better positive effects of POE on experimental group learners' SEBs in the scales of Source and Certainty. Findings suggested that learners achieved better concept achievements and SEBs with the approach of POE inquiry-based learning, which pointed to certain implications for inquiry-based teaching, as well as in education of future science instructors.*
Keywords: *inquiry-based learning model, light refraction, prediction-observation-explanation, science education, scientific epistemological beliefs*

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Introduction

Cultivating the literacy of science has become the main goal in Chinese science education. Özdem (2010) indicated that scientific concept knowledge was one of the important evaluation indicators for scientific literacy, while there has been increasing support for inquiry-based learning as a practical method to develop science learning and improve learners' scientific literacy (Firman et al., 2019; Suarez et al., 2018). For example, Özgür and Yılmaz (2017) studied students' learning of the Acids-bases concepts and showed that inquiry-based learning was a usable approach to improve students' achievement. The Cairns and Areepattamannil (2019) study did show some positive results for dispositions towards science such as science self-concept; however, the results also revealed that inquiry science teaching and science achievement has had a significantly negative correlation. Considering the inconsistent results, it is necessary to study whether the approach of inquiry-based serves science achievement in the different inquiry approaches. Accordingly, this study took POE (Prediction-Observation-Explanation) as the inquiry science learning model, as it has been proven to be a strongly way to learn physical sciences (Latifah et al., 2019). For example, Bunprom et al. (2019) showed that the POE learning strategy helped to overcome eleventh graders' misconceptions of temperature and heat materials. Çalık and Bayçelebi (2020) found that an intervention using the POE learning strategy stimulated fifth graders' conceptions and awareness of healthy nutrition. However, a lack of such an intervention study at the level of fifth grader for learning the concept of light refraction calls for the current study. Whether the POE inquiry learning strategy will also promote the conceptual learning of light refraction for fifth graders remains to be seen. In this study, how POE affects fifth graders' concept achievement while they are involved in learning light refraction was explored.

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Mason and Bromme (2010) defined epistemological beliefs (EB) as "individual representations about knowledge and knowing" (p. 1). EBs was considered to be a crucial factor in interpreting information and knowledge and was therefore related to learners' conceptual understanding during the learning process (Songer & Linn, 1991). Peffer and Ramezani (2019) emphasized the importance of exploring the effects of different teaching methods on scientific epistemological beliefs (SEBs). In the field of educational research, SEBs have been the focus of various science learning studies (Kampa et al., 2016). For example, Liang and Tsai (2010) have stated that learners' SEBs might have an impact on science concept learning, science learning strategy selection (Hsu et al., 2014), and other learning behaviors (Lin et al., 2013). Accordingly, increasing attention has been paid to the impacts of inquiry-based teaching on learners' SEBs. For example, Yang et al. (2019) studied the impacts of the web-based inquiry learning model on SEBs and found that it was beneficial for eighth grader to predict their knowledge integration performance. However, few studies have considered the impacts of applying the POE inquiry-based learning model to the SEBs of children, indicating that research on the SEBs of children was necessary (Zhou et al., 2019). Thus, how POE can activate or deactivate fifth graders' SEBs in learning science was of interest in this study.

According to the cognitive theory of multimedia learning (Mayer, 2014), learning is an active process of filtering, selecting, organizing, and integrating information based on one's prior knowledge. Mayer's CTML presented the learning model in which the brain interprets learning material via a logical mental construction process. In line with this process, this study presented an inquiry-based science learning model, POE, to explore the effects on fifth graders' concept achievements in the Light Refraction unit, and on their SEBs.

Literature Review

Inquiry-Based Learning

The concept of inquiry has a long history in the public school system. Using an inquiry approach to teach science has been emphasized (Gillies & Rafter, 2020). Ketpichainarong et al. (2010) stated the inquiry-based learning refers to the pedagogical strategies that take scientific inquiry and use general processes as the methodology of teaching and learning; it emphasizes students asking questions, investigating, and solving problems. However, the inquiry has many meanings and interpretations, as Cairns and Areepattamannil (2019) discussed. For example, Annisa and Rohaeti (2018) pointed out that inquiry-based learning was an approach that involves asking questions, seeking information, and discovering new ideas that were relevant to an event.

There were many inquiry-based learning models and various inquiry models which had different effects on science learning (Hong et al., 2019). Different inquiry-based learning models facilitated students' understanding of scientific concepts differently (Rakkapao et al., 2014; Bumbacher et al., 2018). Jerrim et al. (2020) found that using inquiry-based teaching was frequently not related to a better science achievement. In other studies, students who frequently experienced inquiry-learning approaches in science courses showed lower levels of science achievement (Areepattamannil et al., 2020; Firman et al., 2019; Özgür & Yılmaz, 2017; Sarwi et al., 2019; Suarez et al., 2018). However, using different inquiry-based models yields different learning results. For example, the POE inquiry-based model is a potential way to promote students' acquisition of conceptions (Hong et al., 2014; Bednar et al., 1992). The study of Arsy et al. (2019) showed that implementing the POE learning strategy with the Group Investigation model was beneficial for training students to discover new knowledge, to improve the achievement and the quality of their learning. However, there was no particular study focused on using POE to explore children's concept achievement in the area of Light Refraction.

The POE Inquiry-Based Learning Model

Pegg (2006) divided the inquiry-based learning model into three categories as follows: a) POCPE model involving the phases of prediction, observation, data collection, and explanation; b) POE model involving the phases of prediction, observation, and explanation; and c) PCMGE model involving the phases of prediction, data collection, measurement, graph making, and explanation. Compared to the other two inquiry-based learning models, POE was a more simplified version. In the POE model, the steps are as follows: a) present the students with a situation; b) ask them to predict about what will happen when changes are made; c) ask for their reasons for their prediction; d) have them perform the change and make observations; and e) have them try to make

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consistent with any conflict between their predictions and observations (Gunstone, 1990). It was common for inquiry-based learning to be arranged into inquiry stages, which were combined to form an inquiry model (Pedaste et al., 2015). A number of different POE inquiry phases and models have been described; they enabled students to connect knew knowledge with their prior knowledge, and helped them absorb the knowledge (e.g., Mamun et al., 2020; Hong et al., 2019). Particularly, Coştu et al. (2012) showed that the teaching strategy of POE-based promoted learners' achievement. Hong et al. (2014) designed learning activities based on the POE inquiry learning model and found that it enhanced students' interest in the topic and their intention to continue to learn science.

Research studies had found that the POE inquiry learning approach contributed to learners' conceptual understanding and learning science (e.g., Arsy et al., 2019; Ayvacı, 2013; Banawi et al., 2019; Chen et al., 2020; Hong et al., 2014; Jasdilla et al., 2018). For example, Chen et al. (2020) implemented the POE strategy in a science inquiry study and proved that POE promoted students' conceptual change and science learning. In addition, Jasdilla et al. (2018) tested the POE strategy, and their results showed that it had effects on fifth-grade students' mental models in science learning. Moreover, the study of Ayvacı (2013) implemented POE inquiry learning with a group of science teachers and concluded that it was effective and attractive for learning scientific concepts. This study focused on how POE could be applied to Light Refraction learning in a science classroom.

Scientific Epistemological Beliefs

William Perry was the first to study epistemological beliefs in learning (1970). His study aimed to better grasp how students interpreted their educational experiences. Epistemological beliefs refer to beliefs about the nature of knowledge and the process of knowing (Hofer & Pintrich, 1997). Hofer and Pintrich (1997) suggested epistemological beliefs consisted of four dimensions, where the "certainty of knowledge" dimension and the "simplicity of knowledge" dimension address the nature of knowledge, while the "source of knowing" dimension and the "justification of knowing" dimension concern the nature of knowing. Hofer and Pintrich's epistemological beliefs theories provided the foundation upon which later research on individuals' epistemological beliefs has been based. For example, based on Hofer's (2000) works, Conley et al. (2004) suggested that the elementary students' scientific epistemic beliefs should be divided into four dimensions. The four dimensions were "source" (e.g., authority or experts are the only source of science knowledge), "certainty" (e.g., there is only one right answer regarding science knowledge), "development" (e.g., science knowledge is a subject of constant development and change), and "justification" (e.g., evidence from different experiments builds the science knowledge), respectively.

Many studies have shown that epistemological beliefs promoted scientific learning (Areepattamannil et al., 2020). She et al.'s (2019) study indicated that epistemological beliefs about science are the most powerful predictors of learners' scientific literacy performance. In Yang et al.'s (2019) study, they examined the effects of the web-based inquiry learning model on SEBs. However, few studies have explored how POE inquiry learning affects children's SEBs; thus, the present study paid attention to the influence of inquiry-based Light Refraction teaching on students' SEBs.

Research Questions

From the results of the several studies described above, there were many benefits to POE. This approach which the teacher incorporated was implemented to assist learners in finding their own knowledge and improving learning quality. However, none of the previous studies in the POE inquiry learning strategy have tested Light Refraction. Moreover, few studies have analyzed the effect on the concept achievements and SEBs of fifth graders when implementing POE learning-based teaching. Therefore, the current study explored the effects of the POE inquiry-based learning model on fifth graders' concept achievement in the unit of Light Refraction and their SEBs, with the aim of answering the following research questions:

1. What are the effects of the POE inquiry-based learning model on fifth graders' concept achievement in Light Refraction?
2. What are the effects of the POE inquiry-based learning model on fifth graders' SEBs in Light Refraction?

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Research Methodology

General Background

In this study, the experiment with pre-test and post-test design was adopted. As shown in Table 1, the control and experimental groups were tested by the Light Refraction Test (LRT) and Scientific Epistemological Beliefs measurement (SEBs), before and after the experiment. The experimental group participated in POE inquiry-based learning, while the control group did not. The study was implemented with fifth graders at a primary school in Jiangsu, China in the fall semester of 2020-2021. The same male science teacher, with 15 years of experience in science teaching, taught all control and experimental groups, and the groups were provided with identical content of Light Refraction.

Table 1
Research Design

Group	Pre-test	Treatment	Post-test
Control	LRT & SEBs	POE inquiry model	LRT & SEBs
Experimental	LRT & SEBs	Conventional	LRT & SEBs

Sample

The research sample was taken from four classes, with a total of 174 fifth grade students, all aged approximately 11 years old. Two classes (46 boys and 40 girls) as the experimental group participated in the POE inquiry learning teaching and the other two classes (45 boys and 43 girls) as the control group participated without the POE inquiry learning. The questionnaire was issued in November 2020, and a total of 174 questionnaires were collected. Randomly filled questionnaires were recorded as invalid. After deleting 23 invalid questionnaires, 151 questionnaires, including 70 from the experimental group (52.9% boys; 47.1% girls) and 81 from the control group (50.6% boys; 49.4% girls), were used for analysis in this study. This study followed the ethical guidelines provided by The Nanjing Normal University of China Human Research Ethics Committee. All participants were completely voluntary, and expressly informed consent, including the privacy measures necessary to protect their privacy interests. In addition, participants were informed that these tests would be used for this research purpose only and free to withdraw at any stage.

Instrument

The Light Refraction Test (LRT)

In science education of Chinese fifth graders, the unit of Light Refraction is taught in the fifth grade. It is important for their future study that students acquire the concept of Light Refraction properly at that age.

The Light Refraction Test was used to measure the fifth graders' concept achievement of Light Refraction both before and after the treatment. Yang et al. (2008) suggested that the design of tests should be based on the science curriculum and teaching objectives. The test of this study mainly assessed the Light Refraction achievement in the basic concepts of Light Refraction. It consisted of five multiple-choice questions and four true-or-false items. One item was marked as one point. One sample of a multiple-choice question was: "Which of the following does not apply the convex lens principle?" And the choices were presbyopic glasses, magnifying glass, and rearview mirror. One sample of a true-or-false item was: "A convex lens can make an object look like an inverted image on a screen, whereas a concave lens cannot." The same questions were applied to the pre-test and post-test, but the order differed. A panel of three science teachers determined the face validity and clarity of each test item. They also analyzed the relationship between the LRT items and the teaching objectives and verified that the LRT instrument had good content validity and measured construct validity, which was suitable for the participating students.

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Scientific Epistemological Beliefs Measurement

A measurement tool that was frequently utilized to evaluate students' SEBs was the Conley et al.'s (2004) questionnaire. This questionnaire contained four subscales and 26 items. The work by Tsai et al. (2011) translated Conley et al.'s SEBs questionnaire into Chinese and validated this questionnaire by surveying students' SEBs. This study revised this Chinese version questionnaire developed by Tsai and adopted a 5-point Likert scale where 1 represents strongly disagree and 5 represents strongly agree. After exploratory factor analysis, six items (two from "source", two from "certainty", one from "development" and one from "justification") were deleted. The revised SEBs measurement's KMO was .742, and Bartlett $p < .05$, indicating that it was suitable for the fifth graders. The overall alpha value was .88, and the four subscales of SEBs' alpha values were above .70 (ranged from .76 to .89). The instrument was therefore considered to be reliable enough to evaluate the fifth graders' SEBs. Detailed descriptions of each of the four subscales (20 items) as well as example items are provided below:

- Source (3 items): Assessing students' beliefs about external authorities and experts as the only source of scientific knowledge. Example item: "In science, you must believe everything you read from the science books" (scored in reverse).
- Certainty (4 items): Reflected students' beliefs in the right answer to knowledge in science. Example item: "Finding the right answer is the most important part of scientific research" (scored in reverse).
- Development (6 items): Assessed students' beliefs about science as a subject that is constantly evolving and changing. Example item: "Some scientific ideas today are different from what scientists used to consider."
- Justification (7 items): Reflected students' beliefs about the role of scientific experiments in science and how they justify scientific knowledge. Example item: "Curiosity and thinking about how things work lead to ideas about science experiments."

Design of a POE Inquiry-Based Learning Model for Light Refraction

The POE learning model was an approach of promoting interest in science courses (Karamustafaoğlu & Mamlok-Naaman, 2015). Pegg (2006) divided the inquiry-based learning model into three categories. In this study, the model 2 involving the phases of prediction, observation, and explanation was applied to Light Refraction to help the students understand the concepts. In this study, the POE learning involved three rounds. Round 1 provided the students with a glass of water and a pen, round 2 with a convex lens and round 3 with a concave lens. Each round of the three phases of "prediction, observation and explanation" are listed as follows and are illustrated in Figure 1.

Prediction 1: Posed a question to guess (3 minutes). The teacher presented a glass of water and a pencil. The question was: After you put a pencil into water, what happens when looking from the top and the side? The students predicted the answers based on their prior knowledge and gave their reasons for the prediction. In this phase, the students were asked questions as a way of promoting their interest and motivation. They did not know whether their answers were right or wrong.

Observation 1: Explored and observed phenomena (20 minutes). A group of students was given a pen and a glass of water; they put the pen into the water, then observed, discussed, and recorded the phenomenon. During this stage, the teacher facilitated their investigation by providing them with books, giving them directions, asking them questions, and encouraging them to explore and observe.

Explanation 1: Answered and explained (17 minutes). After exploring and observing phenomena, the students explained the phenomenon of the pencil looking bent after being put into a glass of water. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted students in finding that traveling from one transparent object to another, light's direction of travel bends at the interface. The teacher helped them to understand the phenomenon of a pen in water and the concept of Light Refraction.

Prediction 2: Posed a question to guess (3 minutes). The teacher presented a convex lens. The question was: What are the shape and imaging features of a convex lens? The students predicted the answers based on their prior knowledge and gave reasons for their prediction.

Observation 2: Explored and observed phenomena (10 minutes). Every student was provided with a convex lens to find reasons for their predictions and performed observations. In this stage, a group of students used a convex lens to observe a tree, which required them to collect their own data about convex lenses and the features of light passing through a convex lens, and to explore and observe certain phenomena.

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Explanation 2: Answered and explained (7 minutes). After exploring and observing phenomena, the students explained the shape and imaging characteristics of a convex lens. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted the students in finding that convex lenses are thick in the middle and thin on both sides, and they can receive light rays from the object and concentrate the light to form an inverted enlarged image. In addition, the teacher helped them to link the concept of a pen in water and the imaging characteristics of a convex lens.

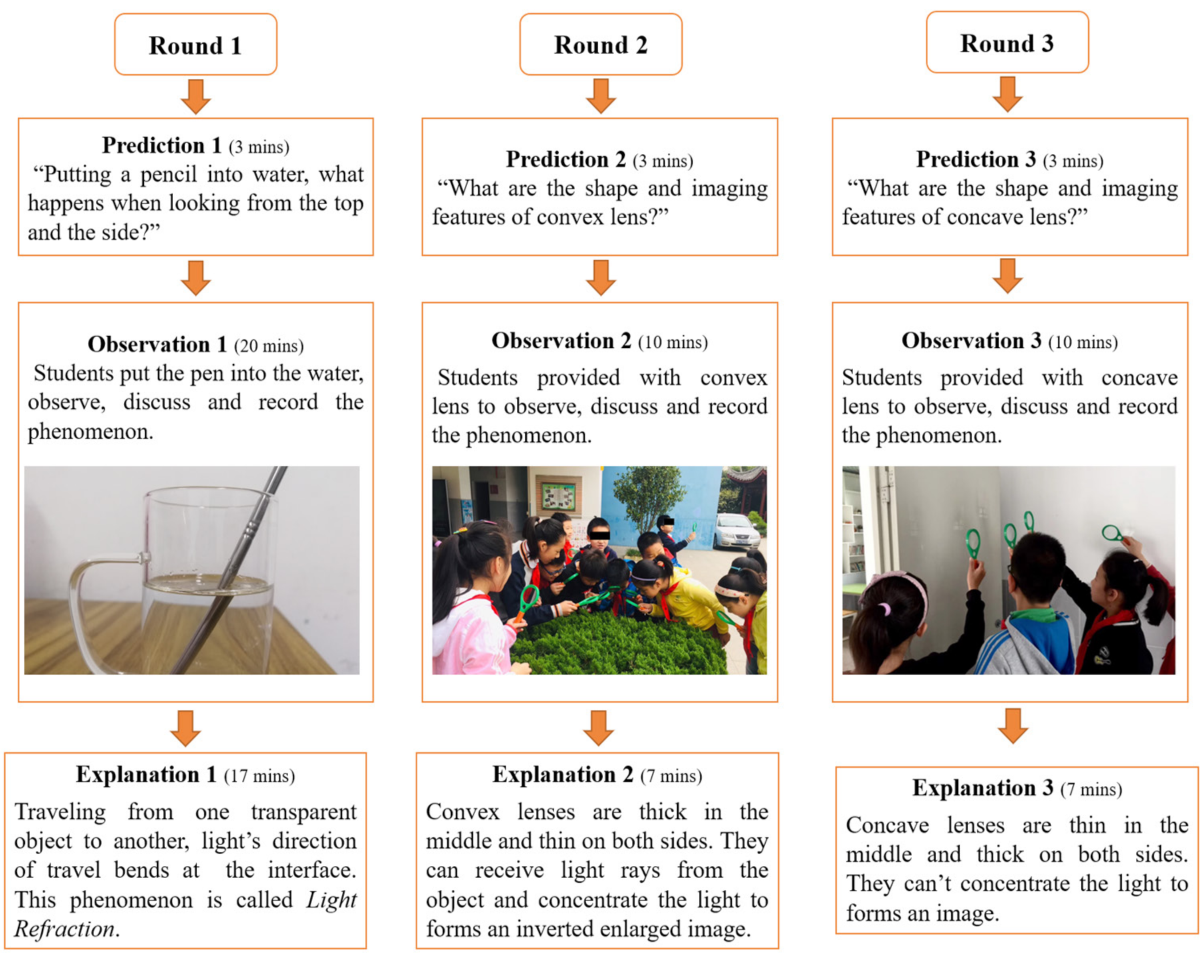
Prediction 3: Posed a question to guess (3 minutes). The teacher presented a concave lens. The question was: What are the shape and imaging features of concave lenses? The students predicted the answers based on their prior knowledge and gave their reasons for the prediction.

Observation 3: Explored and observed phenomena (10 minutes). Every student was provided with a concave lens to find reasons for their predictions and performed observations. In this stage, a group of students used a concave lens to observe the class door, which required them to collect their own data about concave lenses and the features of light passing through a concave lens, and to explore and observe certain phenomena.

Explanation 3: Answered and explained (7 minutes). After exploring and observing phenomena, the students explained the shape and imaging characteristics of a concave lens. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted the students in finding that concave lenses are thin in the middle and thick on both sides, and they can receive light rays from the object, but cannot concentrate the light to form an image. In addition, the teacher helped them to link the concept of imaging features of convex lenses and concave lenses.

Figure 1

The POE Inquiry-Based Model (The Experimental Procedure)



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Procedure

This study was conducted over four 40-minute lessons. In lesson 1 (before the treatment), both groups of students took a pre-test. The LRT and SEBs questionnaires were administered to identify their lens conceptions knowledge, and to understand their SEBs, respectively. In lessons 2 to 3 (during the treatment), the control group participated in traditional teaching without lenses, at the beginning of which concepts related to Light Refraction were explained. The students then read about the content in their textbooks in the classroom, following which teacher conducted Light Refraction experiments based on the textbook. In contrast, the experimental group students performed experimental activities using the POE inquiry learning model. In lesson 2, the experimental group conducted the first round of POE. In lesson 3, the experimental group conducted a second and third round of POE. In lesson 4 (after the treatment), both groups took a post-test. The same instruments were used for all students to understand the effects of the treatment on their Light Refraction concept achievement and their SEBs.

Data Analysis

The pre-test and post-test learning achievement and SEBs data were carried out by SPSS (Statistical Package for the Social Sciences). Basic descriptive statistics (Number in a subsample *N*, mean *M*, standard deviation *SD*) of the numerical variables were determined. An independent sample *t* test was used to analyze the difference in the pre-test and post-test of the learning achievement, SEBs and four SEBs scales. In addition, the significance level of the independent sample *t* test in this research was set to $p = .05$.

Research Results

Concept Achievement of the Unit of Light Refraction

Table 2 shows the independent sample *t* test of the fifth graders learning achievement. No significant difference ($t = .592$, $p = .555$, effect size $d = .101$) was found between the two groups in the pre-test. However, in the post-test, there was a significant difference ($t = -3.835$, $p < .05$, effect size d = -.634) between the two groups. The post-test scores of the experimental group ($M = 6.89$, $SD = 1.246$) were higher than the control group ($M = 6.07$, $SD = 1.340$). The inquiry approach of POE used with the experimental group had more success in terms of promoting learning achievement compared to the traditional teaching.

Table 2
Independent Sample t Test Results of the Two Groups' Learning Achievement

	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Pre-test	Control	81	4.36	1.248	.592	149	.555	.101
	Experimental	70	4.24	1.122				
Post-test	Control	81	6.07	1.340	-3.835	149	< .05	-.634
	Experimental	70	6.89	1.246				

Students' Scientific Epistemological Beliefs

Table 3 shows the independent sample *t* test of the fifth graders' SEBs. As we can see for the two groups, the scores in post-test were higher than the pre-test. The pre-test results showed no significant difference between the two groups ($t = -.334$, $p = .731$, effect size $d = -.043$). However, in the post-test, there was a significant difference ($t = -3.676$, $p < .05$, effect size $d = -.609$) between the two groups. The average SEBs scores of the experimental group ($M = 3.47$, $SD = .294$) were higher than the control group ($M = 3.28$, $SD = .329$), indicating that the POE teaching which the experimental group received had more success in terms of promoting SEBs compared to the traditional teaching.

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Table 3
Independent Sample t Test Results of the Two Groups' SEBs

	Group	N	M	SD	t	df	p	d
Pre-test	Control	81	3.09	.398	-.334	149	. 731	-.043
	Experimental	70	3.11	.530				
Post-test	Control	81	3.28	.329	-3.676	149	< .05	-.609
	Experimental	70	3.47	.294				

The independent sample *t* test was employed to analyze the pre-test of the four SEBs scales. Table 4 shows that the four scales of "Source" (t = -1.118, p = .276, effect size d = -.174), "Certainty" (t = 1.56, p = .121, effect size d = .252), "Development" (t = -0.175, p = .861, effect size d = -.037) and "Justification" (t = -1.188, p = .237, effect size d = -.187) showed no significant difference in the pre-test.

Table 4
Independent Sample t Test Results of the Items of the Two Groups' Pre-test SEBs

Item	Group	N	M	SD	t	df	p	d
Source	Control	81	2.67	1.122	-1.118	144.39	.276	-.174
	Experimental	70	2.84	.806				
Certainly	Control	81	2.92	.783	1.56	149	.121	.252
	Experimental	70	2.70	.952				
Development	Control	81	3.72	.671	-.175	123.946	.861	-.037
	Experimental	70	3.75	.925				
Justification	Control	81	3.91	.481	-1.188	112.6	.237	-.187
	Experimental	70	4.03	.767				

The independent sample *t* test was employed to analyze the post-test of the four SEBs scales. In the post-test, Table 5 shows that there was a significant difference in the "Source" (t = -5.923, p < .05, effect size d = -.975) and "Certainty" (t = -2.914, p < .05, effect size d = -.463) scales between the experimental group and control group. The average SEBs score of the experimental group (M = 3.71, SD = .861) was significantly better than that of the control group (M = 2.95, SD = .689) in the Source scale. The average SEBs score of the experimental group (M = 3.10, SD = .830) was significantly better than that of the control group (M = 2.77, SD = .572) in the Certainty scale. However, there was no difference in the "Development" (t = -0.603, p = .548, effect size d = .088) or "Justification" (t = -.829, p = .414, effect size d = -.135) scales.

Table 5
Independent Sample t Test Results of the Items of the Two Groups' Post-test SEBs

Item	Group	N	M	SD	t	df	p	d
Source	Control	81	2.95	.861	-5.923	149	< .05	-.975
	Experimental	70	3.71	.689				
Certainty	Control	81	2.77	.830	-2.914	142.214	< .05	-.463
	Experimental	70	3.10	.572				

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Item	Group	N	M	SD	t	df	p	d
Development	Control	81	4.10	.496	.603	149	.548	.088
	Experimental	70	4.05	.629				
Justification	Control	81	4.18	.478	-.829	149	.414	-.135
	Experimental	70	4.25	.555				

Discussion

The Practice of POE Improved Fifth Graders' Learning Achievement

Through participating in explorations and discussion activities, the experimental group students regulated their thinking about their prior knowledge and reflected on it, in order to form their own connections among the science concepts (Jerrim et al., 2020; Zhang, 2019). Accordingly, one of the aims of the study was to explore the different influences of the POE learning inquiry model and traditional teaching on fifth graders' concept achievement in the Light Refraction unit. According to the independent sample *t* test results, students in the two groups had similar prior knowledge in Light Refraction, but there were significant differences in their knowledge after the intervention, indicating that there were significant differences in the influence of the two methods of teaching on fifth graders' concept achievement of Light Refraction. The result was supported by some previous studies, for example, POE inquiry learning promoted students' learning of scientific concepts (Bunprom et al., 2019; Fitriani et al., 2020; Karamustafaoğlu & Mamlok-Naaman, 2015), indicating that the POE inquiry-based learning method was more effective than traditional teaching in terms of learners' learning of the concepts of Light Refraction.

The POE Inquiry-Based Learning Model Improved Fifth Graders' SEBs

The students' SEBs are generated between knowledge claims and draw on experiences of the knowledge building process (Kienhues et al., 2016), where POE regulating the process of knowing is particularly relevant for knowledge comprehension (Braten et al., 2015). Based on the independent sample *t* test results, both the experimental and control group learners' prior SEBs were similar, but there was a significant difference in their SEBs after the intervention, indicating that the experimental group could lead to better SEBs than the control group. The findings supported the earlier studies which also found positive effects of POE on students' SEBs (Chen, 2017; Cheng, 2018), indicating a significant difference in the "Source" and "Certainty" dimensions for the control group and experimental group. However, there was no difference in the "Development" or "Justification" dimensions. The results were parallel to the findings of Conley et al.'s (2004), which suggested that students develop SEBs that more sophisticated "source" and "certainty" were constructed and without significantly changing beliefs about "development" and "justifications." Therefore, the approach of POE inquiry learning facilitated the fifth graders' "Source" and "Certainty" dimensions in two 40-minute lessons.

The POE applied to Light Refraction learning was designed to encourage prediction, observation, and explanation, but it ignored argumentation. In addition, the time of the observation phase took half of each lesson. It was obvious that emphasizing observation limited the opportunities of the learners to use evidence to debate their ideas and to reflect on their inquiry activities. This might account for the lack of significant change in the dimensions of development and justification. The underlying mechanism of this change should be more validated in studies that make comparisons with science classrooms that adopt inquiry-based teaching strategies with a focus on argumentation and reflection (Herrenkohl et al., 1999).

Conclusions and Implications

This study presented the three round POE inquiry-based learning in the Light Refraction unit and explored its effects on fifth graders' concept achievements and their SEBs. It could be concluded that learners achieved

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better concept achievements and SEBs in POE inquiry-based learning. In addition, it showed better positive effects of POE inquiry-based learning on learners' SEBs in the subscales of "source" and "certainty". Therefore, when using the POE inquiry-based model teaching, instructors were suggested to strengthen the cultivation of learners' SEBs in the scales of "development" and "justifications."

The implementation of the POE inquiry-based learning model is expected to provide theoretically and practically help for learners to learn simple science concepts. Theoretically, this implementation can help learners to improve their concept achievement, and to build views of their own knowledge and knowing in science. Practically, the overall results of the present research suggest that when learners practice POE, it can help them understand Light Refraction and achieve better learning performance. Therefore, the POE model can be applied to promote students' science learning and help learners gain a better understanding of exactly the generation and development of scientific knowledge. This study has some enlightenment for instructors that it needs to design different inquiry models according to different scientific concepts so as to effectively improve learner's concept achievement. It is of great significance to the education system of science instructors and enhancing their competencies for inquiry-based teaching.

The implementation of the POE inquiry-based learning model is expected to provide the help for improving learners' SEBs. Learners' SEBs can be strengthened based on applying the POE learning-based model to teaching. Therefore, it is suggested that instructors use the POE learning-based model in science courses to improve learners' SEBs. It is very important that the instructor applies inquiry teaching strategies to make learners play an active role in the teaching process. This study has an important contribution for instructors to design the teaching process using POE inquiry-based model teaching strategies. In scientific learning inquiry, there is often more than one prediction or question. If all of the predictions and questions are put at the beginning phase, it may be difficult to focus on the one prediction. However, if one POE model is explored one prediction in one round, many details can be focused on. Therefore, if there are a lot of predictions, it is suggested that instructors construct learners' SEBs one prediction at a time, and one POE model at a time.

Limitations

This study has some limitations. The study implemented one unit of teaching. Therefore, the suitability of the POE inquiry model for other new units or new subjects is not certain. Thus, future studies can select more units or topics of science to conduct POE for students to learn and examine their SEBs and learning achievement. Teachers have been found to hold sophisticated scientific epistemological beliefs. Education can be enhanced if teachers are asked to examine their belief structures. This might in turn impact their SEBs beliefs about teachers' and students' roles. Therefore, in the future, it is suggested that the focus be on research of teachers' epistemological beliefs, especially in science education, and on what types of experiences impact the development of these beliefs and conceptions. In addition, due to the period of this study being short, with just 80 minutes over a period of two classes, the results of this study suggested that learners developed SEBs that the more sophisticated "source" and "certainty" were constructed and without significantly changing beliefs about "development" and "justifications." Therefore, future studies may implement longer experiments to explore if the POE inquiry learning teaching can facilitate the students' "Source" and "Certainty" dimensions.

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Declaration of Interest

Authors declare no competing interest.

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PRIMARY STUDENTS' PERFORMANCE OF STEM DOMAIN-SPECIFIC SELF-EFFICACY BELIEF AND EXPECTANCY-VALUE BELIEF

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Abstract. *Most studies have concentrated in assessing students' overall attitudes towards science, mathematics, and engineering/technology or the attitude towards individual STEM domain. The present research aims to explore primary students' gender and grade differences of their STEM domain-specific attitudes including self-efficacy and expectancy-value beliefs, as well as their correlations. The results showed no detected significant effects among these different STEM domains in the overall attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs for primary students. The correlations between self-efficacy and expectancy-value were much stronger for the science domain and engineering/technology domain than the mathematics domain. No gender difference of the self-efficacy beliefs was detected except in the mathematics domain, and the result that lower primary students performed significantly better than upper primary students in the self-efficacy was also mainly contributed by the grade difference in the mathematics domain. Whereas no different expectancy-value beliefs existed across genders and grade levels in various STEM domains. The present results reported some unique performances by the primary school students compared to the elder group.*

Keywords: *expectancy-value, gender differences, grade levels, self-efficacy, STEM attitudes*

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Introduction

Nowadays, the developments of information and communication technology occurring with globalization have affected the lives and economies of all nations. The common motivation for countries around the world today is to improve the educational system to make the new generation more innovative and creative (Lederman, 2008). Demand has also increased for countries which would develop new technologies and produce more valuable and innovative products (Ergun, 2019). For example, workers in the field of science, technology, engineering, and math (STEM) are favored in the United States (Carnevale et al., 2011; Rothwell, 2013), and it has been predicted that the demand of STEM workers will continue for years (National Academy of Engineering, 2008; Unfried et al., 2015). It is stated that STEM skills are necessary for everyone, not only those who want to pursue STEM careers, but also those who do not (Yerdelen et al., 2016). Students need to actively improve their STEM capabilities to cope with the challenges of globalization and the development of the knowledge-based economy (Kristen et al., 2012). Therefore, the economic globalization encourages individuals to make adequate efforts and preparations to improve STEM literacy and to pursue STEM related careers (Yerdelen et al., 2016).

In educational field, with countries recognizing the role of STEM education in the future's economy, improving students' STEM learning has become a top priority (McMahon & Showers, 2012). STEM education has been considered as a government policy in the United States, (National Research Council [NRC], 2010) and the interest in STEM disciplines has increased in many European countries (Corlu et al., 2014). STEM Education has also been regarded as one of the hot topics in the ministry of education of many countries, such as China (Zhou et al., 2019) and Turkey (Yerdelen et al., 2016). Generally, improving students' attitudes towards STEM could raise the possibilities of students to choose STEM careers in the future. Therefore, the importance of STEM education requires more attention to the attitudes towards STEM-related domains from kindergarten kids through

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K-12 school students (Business-Higher Education Forum, 2010; President's Committee of Advisors on Science and Technology [PCAST], 2010).

However, many countries around the world are facing a common challenge of decreasing numbers of students who show interest in the STEM-related disciplines (National Science Board [NSB], 2012; Osborne & Dillon, 2008). It is reported that more than three times as many graduates in humanities and social sciences than those in STEM-related major in the Organization for Economic Co-operation and Development (OECD) countries (OECD, 2015). It is noted that only a small number of students starting higher education have chosen STEM-related disciplines among the OECD countries (OECD, 2017). Additionally, compared with other fields, more students drop out of STEM disciplines which they have chosen in the first place (Reinhold et al., 2018). It is stated that the number of students in higher education institutions choosing STEM related majors is much lower than expected (Shapiro & Sax, 2011). As it has been reported by University of California at Los Angeles (UCLA), many K-12 and post-secondary students lost interest in STEM, with nearly half of engineering and science majors switched to other majors or failed to get a degree (Drew, 2011). Besides, according to previous research, the number of students who value STEM in universities in developing countries has also decreased over the years (Akgunduz, 2016).

Naturally, poor academic performance affects the number of students who complete higher education degrees and enter STEM-related professions (Christensen et al., 2014). Many capable students do not choose STEM-related fields as their careers in many countries such as United States. As a result, the rate of choosing STEM-related fields as a career is generally low (Kizilay, 2018). Globally, the demands about labor force in STEM-related fields are not being adequately met (Atkinson, 2013; Moakler & Kim, 2014). For example, only 300,000 students with STEM-related majors in the United States are graduating each year, while the demand for the workforce is expected to be close to one million (Holdren & Lander, 2012).

Literature Review

Due to the continuous extension of the research on students' attitudes, researchers' understanding of attitudes has been deepened, which leads to the continuous expansion and evolution of the definition of attitudes (Luo et al., 2019). Students' attitude towards a subject is considered to be an important correlation of achievement motivation, which consists of two important components, namely, self-efficacy belief and expectancy-value belief (Eccles & Wigfield, 2002). Self-efficacy was described by Bandura (1997) as an individual's confidence in their ability to accomplish a task. Researchers have found increasing evidence that self-efficacy could be considered as a predictor of academic achievement (Multon et al., 1991; Zimmerman & Bandura, 1994). According to the previous studies, students are more likely to continue postsecondary education in STEM domain if they show higher self-efficacy in math (Wang, 2013) or science (Scott & Mallinckrodt, 2005). As for expectancy-value theory, first proposed by Atkinson in the 1950s, it has since been expanded into educational field to address students' achievement-related choices (Wigfield & Eccles 2000). Expectancy-value theory holds that individuals periodically evaluate their likelihood of achieving certain goals and evaluate the specific value gained or lost in achieving those goals (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). According to the different connotations of expectancy-value belief, Bandura divided it into two sub-dimensions, that is, outcome expectations belief and efficacy expectations belief (Luo et al., 2019). Outcome expectations belief represents that certain behaviors will lead to certain outcomes (e.g., "the belief that practicing will improve one's performance") and efficacy expectations belief indicates whether individual is capable of performing effective behaviors necessary to generate outcome (e.g., "I can practice sufficiently hard to win the next tennis match"). Whether one has high expectations has been demonstrated to be closely related to one's adherence to advanced math and science courses (Fan, 2011; Simpkins et al., 2006). When studying career aspirations model, expectancy-value theory is regarded as a supplement to self-efficacy theory (Schunk, 1991; Wigfield & Eccles, 2000). For the purposes of the present research, students' attitudes are defined in alignment with Eccles and Wigfield's (2002) description focusing on self-efficacy and expectancy-value beliefs. In addition, this research takes interest in such beliefs towards STEM disciplines across genders and grade levels.

Research on the attitudes towards various core STEM subjects

Since the 1970s, research on students' attitudes towards science and math has produced an impressive body of research literature (e.g., Aiken, 1970; Gardner, 1975; Osborn et al., 2003; Potvin & Hasni, 2014b; Simpson

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& Oliver, 1990). The research literature has also emerged with surveys measuring students' attitudes towards a single STEM discipline (Unfried et al., 2014). Typically, students' interests and expectations in math or science are of primary concern to the researchers (Wiebe et al., 2018). For instance, the Test of Science-Related Attitudes (TOSRA) is an instrument that consists of seven subscales with 10 items each, measuring student attitudes towards science in the secondary education period (Fraser, 1978). Affective Elements of Science Learning Questionnaire is another assessment of student attitudes towards science (Williams et al., 2011). Another instrument is the Attitudes Towards Mathematics Survey (Miller et al, 1996), which aims at measuring student attitudes towards mathematics. In contrast to the literature that measures students' attitudes towards science and mathematics, less research has focused on students' attitudes towards technology and engineering areas (Johnpaul et al., 2018). Different tendencies of this kind of research have even led a part of researchers to a question whether science and mathematics alone are worthy of attention, rather than integrating technology and engineering as elements to be the whole of STEM area (Lederman & Lederman, 2013). Studies which focus on technology aspect of STEM, tend to view the technology itself as a toolbox of skills that could be applied to science and mathematics, rather than as a primary and unique domain of STEM (Kennedy et al., 2018). Unlike other instruments, Erkut and Marx (2005) developed an instrument for the survey of attitudes towards multiple STEM areas: science, math, and engineering/technology. This instrument could be applied to assess students' attitudes towards different STEM disciplines for understanding their similarities and differences (Johnpaul et al., 2018). It is necessary to systematically gather data of attitudes for young students across various STEM domains (Minner et al., 2012).

In the present research, the differences were examined, in attitudes towards all core STEM subjects (science, math and engineering/technology) and interests in STEM careers among 1st through 6th grade students. This research also focused on primary students' performances in self-efficacy and expectancy-value beliefs towards various STEM domains.

Student attitudes towards STEM across genders and grade levels

In terms of gender, it was found that contradictory evidence existed on student attitudes towards STEM (Toma & Greca, 2018). Most research studies suggested that boy students tended to have more positive attitudes towards STEM than girl students (Greenfield, 1996; Jarvis & Pell, 2005; Jones et al., 2000). On the contrary, some studies indicated that students did not exhibit significant difference in the attitudes towards STEM across genders (Akpinar et al., 2009; Zhou et al., 2019). Even, it has also been found that the attitude of boy students towards STEM was less positive compared to girl students (Boone, 1997). As well, other studies have examined gender differences in student attitudes towards STEM sub-disciplines (Wiebe et al., 2018), such as science (Akpinar et al., 2009; Toma & Greca, 2018), mathematics (Watt et al., 2012), engineering, and technology (Unfried et al., 2014). Eccles pointed out that the underlying reasons for the differences in STEM attitudes based on gender were nuanced (Eccles & Wigfield, 2002).

More specifically, recent reviews which covered gender differences across STEM disciplines found that gender differences in self-efficacy existed across most of the STEM domains (Eddy & Brownell, 2016; Cheryan et al., 2017). Cheryan et al. (2017) stated that gender differences in self-efficacy predicted the different participation rates for girls in STEM disciplines. Compared with girls, boys have higher expectations for success in STEM fields (Yee & Eccles, 1988). This difference could explain the decreased enrollment in STEM-related courses for girls (Watt et al., 2012). Gender differences in STEM achievement may be influenced by the amount of value that boys and girls place on STEM domains as well. However, many studies indicated no gender differences in the expectancy-value levels of STEM (Eccles, 2009). It can be seen that gender differences in students' attitude states in high school or college have been examined individually in prior studies, but not students' self-efficacy and expectancy-value beliefs in primary school. It is necessary to do further investigation among primary graders.

From the aspect of grade levels, a number of studies have paid attention to the grade differences in STEM attitudes involving students from primary school through university. Many studies have determined a common result that older graders have a less positive attitude towards STEM domains compared to younger graders (Potvin & Hasni, 2014a; Unfried et al., 2014). For instance, a group of international and Australian longitudinal studies showed that student attitudes towards STEM steadily declined due to students' transitioning to early high school (e.g., Speering & Rennie, 1996). Attitudes towards science have also been found to decline from upper primary school to middle school in a longitudinal study (Unfried et al., 2014). The previous research has determined that lower primary students performed much more positive attitudes than upper primary students

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(Zhou et al., 2019). However, there were contradictory results in some existing studies, in which some showed no significant differences across grade levels, while others supported an increase in student attitudes towards STEM domains as the grade grew (Akpinar et al., 2009; Ali et al., 2013; Said et al., 2016). In addition, grade level has been considered to be a significant factor, having interactions with gender on STEM learning attitudes (Wiebe et al., 2018). In general, student attitudes towards STEM fields have been examined across grade levels for different graders in prior research. The prior research on primary students' attitudes towards STEM also contributed to the related literature (Zhou et al., 2019). A more nuanced research on differences of attitudes across various STEM disciplines is worthy of subsequent exploration. Further, it makes sense to investigate the grade level difference of students' self-efficacy and expectancy-value beliefs towards STEM domains in primary grades.

The relationship between self-efficacy belief and expectancy-value belief

There are various correlations among various variables of STEM attitudes in the literature. One research, on the one hand, found little relation between self-efficacy and outcome expectancy in STEM-related domains (Maddux et al., 1986). On the other hand, for the science attitudes, moderate correlations exist between the perceived usefulness of school science for scientific careers and each of self-efficacy, enjoyability, relevance, and intentions. For the mathematics attitudes, there is a moderate correlation between self-efficacy and enjoyability. As well, there are moderate correlations between the different attitudes towards design technologies (Johnpaul et al., 2018).

Regarding two essential components of student attitudes towards STEM, Bandura's self-efficacy theory focuses on expectancy for success based on expectancy-value theory and attribution theory (Luo et al., 2019). Manning and Wright (1983) found a strong correlation (r=.75) between self-efficacy and outcome expectancy. Self-efficacy was modeled as a determinant of outcome expectancies, interests, and intentions (Fouad & Smith, 1996). Self-efficacy is considered as a compelling predictor of STEM academic success and the willingness of students to set challenging goals like a STEM educational pathway. Wang (2013) found that a college student's intent to major in STEM was directly affected by his or her 12th-grade math achievement, exposure to math and science courses, and math self-efficacy beliefs. During high school, having high expectancy-value beliefs has been found to be associated with a student's persistence in taking both advanced science and mathematics courses (Simpkins et al., 2006). Research studies have shown that students were more likely to pursue postsecondary schooling in STEM fields if they had success in mathematics (Wang, 2012) or high self-efficacy in science (Scott & Mallinckrodt, 2005) in earlier grades.

Research Questions

In the early studies of the development of social psychology, researchers explored the impact of demographics including age, gender, and race on self-efficacy, outcome expectations, and career interests (Fouad & Smith, 1996). In one of the previous studies, the researchers studied the factors affecting students' attitudes towards STEM domains and found that gender had an interactive effect on attitudes and interests in STEM professions (Unfried et al., 2014). Recently, some studies have found a positive effect of STEM oriented interventions on students' STEM career interests (e.g., Peterman et al., 2016; Xie & Reider, 2014). The researchers have emphasized that self-efficacy and expectancy-value form a core structure that can influence motivation and persistence in the academic trajectory (Schunk, 1991; Wigfield & Eccles, 2000). What's more, relevant studies have demonstrated the need to distinguish differences between general self-efficacy and specific self-efficacy towards specific academic domains (Chen et al., 2000). However, there has been less related research about STEM attitudes involving primary students from grade one to grade three as emphasized in the previous research (Zhou et al., 2019). It suggests that there is a need to study the attitudes towards STEM among students through all grade levels in primary school. Therefore, the purpose of this research was to extend the previous research (Zhou et al., 2019) to examine differences of primary students' domain-specific STEM attitudes in terms of genders or grade levels, and to explore the correlation between students' STEM self-efficacy and expectancy-value beliefs. Three research questions were as follows:

1. What is the correlation between STEM domain-specific self-efficacy and expectancy-value beliefs?
2. Is there a significant difference of primary students' STEM domain-specific attitudes in terms of gender or grade level?

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Research Methodology

General Background

The present research was an extension of the previous research (Zhou et al., 2019), which explored the performance of primary students in overall STEM attitude and the improvement of students' STEM attitude after receiving a twelve-week integrated STEM project. In this previous research, STEM attitude was regarded as a unified disciplinary attitude, which was not divided neither according to the different domains of STEM nor according to the dimensions of self-efficacy belief and expectancy-value belief. The present research also took primary school students as the research object but focused on understanding more multi-layered states of students' STEM attitudes. The data for this research were excavated from the same research program in the previous research (Zhou et al., 2019), in which the data were collected in 2018, and the in-depth data mining was conducted during the period 2019-2020. From the perspective of different domains, it is worth exploring whether there were differences in students' attitudes towards STEM in various STEM domains and extracting gender differences and grade level differences on this basis. In addition, from different dimensions of STEM attitude, this research also aimed to explore whether there were differences in the self-efficacy belief and expectancy-value belief of primary school students, and whether the difference was found in different STEM fields, different genders, and different ages.

Sample Selection

In order to study how primary students exhibit different attitudes towards STEM according to gender and grade level, and to explore the relationship between primary students' STEM self-efficacy and expectancy-value, the participants were selected from grade one through grade six in primary school in China. The primary school is an ordinary one in a Guangdong Province in China, with no special teaching intervention in STEM education beyond the curriculum standards of the Ministry of Education (MoE) of China. All the students voluntarily participated in the present research and with the consent of their parents. Based on the above principles, the participants and the ratio of boys to girls in different grades were different. The population contained 127 boys and 54 girls, with a total number of 181 primary school students. The distribution of boys and girls in different grades is shown in Table 1.

Table 1
The Distribution of Boys and Girls in Different Grades in the Research

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Total
Boys	7	17	34	36	11	22	127
Girls	5	4	14	15	10	6	54
Total	12	21	48	51	21	28	181

Instrument and Procedures

There have been many studies designed to provide validity evidence for evaluating students' attitudes towards a single discipline or integrated STEM areas at different levels of the education system (e.g., Adams et al., 2006; Lent et al., 2008). Although there were a limited number of studies attempting to investigate students' STEM attitudes during the K-12 school year, some new assessments still show promise (e.g., Unfried et al., 2015).

In the previous research, the S-STEM survey which developed from North Carolina State University was used to assess primary students' STEM attitudes (Unfried et al., 2015; Zhou et al., 2019). Within the entire S-STEM survey, there are 26 items assessing students' STEM attitudes based on three dimensions: science (9 items), math (8 items), and engineering and technology (9 items) (Yerdelen et al., 2016). The survey also contains 11 items assessing students' 21st century skills. As this subscale was not relevant to the present research, it was not introduced and analyzed below. Each dimension consists of both self-efficacy items, such as 'I am sure I could

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do advanced work in math', and expectancy-value items such as 'I will need a good understanding of math for my future work' (Wiebe et al., 2018). Table 2 describes items representing the attitudes towards different disciplines and the statements comprising categories. The S-STEM survey uses a five-point Likert scale from strongly disagree to strongly agree on a scale of 1 to 5.

Table 2
Descriptions and Categories of Items in S-STEM Survey

Discipline categories	Statements comprising categories	
	Self-efficacy	Expectancy-value
Math	1,3,4,5,7,8	2,6
Science	9,14,16	10,11,12,13,15,17
Engineering and Technology	18,20,21,23,26	19,22,24,25

The S-STEM survey has an upper primary version for 4th and 5th graders in primary schools as described in the previous research (Wiebe et al., 2018). The validity evidence on the S-STEM survey has been proved by previous research studies (Unfried et al., 2015; Luo et al., 2019). In the present research, this version has been translated into Chinese as simple and suitable, as possible for lower primary graders by two of the researchers. It took each student about 20 minutes to complete the S-STEM survey. Especially for first and second graders, the teacher needed to read each item when necessary to make sure the meanings of all items were understood by students (Zhou et al., 2019).

Data Analysis

SPSS Statistics was applied for the test on S-STEM to establish their reliability evidence. The reliability (Cronbach's alpha) coefficient was .896, indicating sufficient consistencies in the outcome of the test in present research. The data support the use of the S-STEM survey for the investigation. Besides, various categories of student attitudes towards STEM across genders and grades (lower primary students and upper primary students) are compared, using the analysis of variance (ANOVA) statistic and the independent sample *t*-test statistic. Also, the correlation analysis and linear regression analysis were used to test the correlation between primary students' self-efficacy and expectancy-value beliefs towards STEM subjects.

Research Results

Students' STEM Domain-specific Self-efficacy and Expectancy-value Beliefs

The overall mean score of the whole population in the STEM survey was higher than 3 (M=3.61, SD=.81), indicating a positive exhibition of students' STEM attitudes. One of the research aims was to explore whether primary students exhibited different attitudes towards three sub-dimensions as science, mathematics, and engineering/technology. Therefore, this research compared students' performances on the overall STEM attitudes and different categories of attitudes including self-efficacy and expectancy-value, across three different sub-dimensions of STEM areas.

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Table 3
Correlation Matrix for Attitudinal Constructs within Students' STEM Domain-specific Attitudes Profile

	N	STEM attitudes Mean Score (SD)	Self-efficacy Mean Score (SD)	Expectancy-value Mean Score (SD)	Correlation coefficient between Self-efficacy and Expectancy-value
Total	181	3.61(.81)	3.64(.88)	3.54(.95)	
Mathematics		3.61(.81)	3.66(.92)	3.45(1.02)	.374**
Science		3.52(.81)	3.55(.88)	3.50(.91)	.628**
Engineering/ Technology		3.69(.81)	3.70(.85)	3.68(.90)	.742**
F		2.14	1.37	2.84	
p-value		.118	.255	.059	
η^2		.008	.005	.010	

$^{**}p<.01$

Table 3 illustrates the descriptive statistics of students' performances on the sub-dimensions of students' STEM attitudes. The mean (*M*) and standard deviation (*SD*) of the scores are presented, along with the results of analysis of variance (ANOVA) statistic. For the overall STEM attitudes, students achieve a little higher mean score in engineering/technology domain than those in the science and mathematics areas. As shown in table 3, students' performance in engineering/technology domain has the highest construct average (*M*=3.69, *SD*=.81), followed by the mathematics domain (*M*=3.61, *SD*=.81), while student performance in science domain has the lowest average (*M*=3.52, *SD*=.81). However, no significant effect was detected on STEM domains for overall STEM attitudes ($F(2,540)=2.14$, $p=.118$, $\eta^2=.008$). Although students performed a little better in engineering/technology domain than in both mathematics and science domains, there were no detected significant effects for the self-efficacy category ($F(2,540)=1.37$, $p=.255$, $\eta^2=.005$) and for the expectancy-value category ($F(2,540)=2.84$, $p=.059$, $\eta^2=.010$) among three different sub-dimensions of STEM areas.

Another aim of this research was to examine the correlation between self-efficacy belief and expectancy-value belief in STEM academic domains. In order to explore whether there was a correlation between primary students' STEM self-efficacy and expectancy-value beliefs, a liner correlation analysis was applied. From the results of the correlation test in Table 3, for the science attitudes, there was a moderate correlation between self-efficacy and expectancy-value beliefs ($r=.628^{**}$). Also, a significant positive correlation existed between self-efficacy and expectancy-value beliefs for attitudes towards engineering/technology domain ($r=.742^{**}$). In addition, the correlation between mathematics self-efficacy and expectancy-value beliefs was much more weaker ($r=.374^{**}$).

Differences of Students' STEM Domain-specific Attitudes in terms of Genders or Grade levels

The second goal of the research was to explore whether primary students exhibited different attitudes towards various STEM domains among groups in terms of genders or grade levels. Thus, students' performances were compared not only on the overall STEM attitude, but also on both the self-efficacy category and the expectancy-value category according to gender and grade level. In terms of grade levels, as introduced in the previous research (Zhou et al., 2019), students in the primary level were categorized as lower primary group with students from grade one to grade three and upper primary group with students from grade four to grade six.

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Table 4
The Mean Score for Each Group of Students and the T-test Statistic Results

	N	STEM attitudes Mean Score (SD)				Self-efficacy Mean Score (SD)				Expectancy-value Mean Score (SD)			
		Boys	Girls	Lower primary group	Upper primary group	Boys	Girls	Lower primary group	Upper primary group	Boys	Girls	Lower primary group	Upper primary group
Overall		3.64(.63)	3.52(.53)	3.71 (.59)	3.52 (.60)	3.69(.89)	3.53 (.85)	3.74 (.87)	3.56 (.89)	3.55(.97)	3.53(.91)	3.62 (.96)	3.48 (.94)
t (p)		1.25(.211)		2.07(.040)		1.86(.064)		2.26(.024)		.141(.888)		1.75(.080)	
Mathematics		3.69(.83)	3.43(.73)	3.76(.73)	3.49(.85)	3.78(.94)	3.40 (.84)	3.85(.83)	3.52(.97)	3.43(1.04)	3.51(.99)	3.51(1.06)	3.41(1.00)
t (p)		2.02(.045)		2.32(.022)		2.55(.012)		2.42(.016)		-.480(.631)		.627(.531)	
Science	181	3.52(.84)	3.49(.76)	3.57(.84)	3.47(.79)	3.54(.87)	3.58(.90)	3.54(.95)	3.57(.81)	3.51(.95)	3.45(.82)	3.58(.95)	3.43(.88)
t (p)		.227(.821)		.769(.443)		-.259(.796)		-.267(.790)		.457(.649)		1.15(.250)	
Engineering/ Technology		3.72(.82)	3.63(.80)	3.80(.74)	3.60(.86)	3.74(.87)	3.62 (.80)	3.82(.79)	3.60(.89)	3.69(.90)	3.64(.91)	3.77(.85)	3.60(.94)
t (p)		.688(.492)		1.66(.099)		.871(.385)		1.75(.082)		.368(.714)		1.32(.190)	

Table 4 presents the mean score for each group of students and the results of t-test statistic. In terms of genders, there was no significant difference between boy students and girl students in the overall STEM attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs, regardless of different STEM domains. While in terms of grade levels, lower primary students performed significantly better than upper primary students not only in the overall self-efficacy category (t=2.26, df=179, p=.024), but also in the overall STEM attitude (t=2.07, df=179, p=.040), with the later result clearly identified in the previous result (Zhou et al., 2019). However, in the overall expectancy-value category, although lower primary students (M=3.62, SD=.96) achieved a little higher mean score than upper primary students (M=3.48, SD=.94), no statistically significant difference was consistently detected between the two groups (t=1.75, df=179, p=.080).

In regard to student attitudes towards various STEM domains, the statistical data in science and engineering/technology domains indicated that there was no significant difference either between boy students and girl students or between lower primary students and upper primary students in the overall STEM attitude, the overall self-efficacy category, and the overall expectancy-value category.

However, considering the mathematics attitude, the statistical value indicated that there was a significant difference (t=2.02, df=179, p=.045) between boy students and girl students, with better performance of boy students (M=3.69, SD=.83) than that of girl students (M=3.43, SD=.73). Meanwhile, a significant effect was detected in terms of grade levels of mathematics attitude (t=2.32, df=179, p=.022), indicating that students in lower primary group (M=3.76, SD=.73) performed much better than students in upper primary group (M=3.49, SD=.85). Obviously, the differences were mainly reflected in the mathematics self-efficacy beliefs among groups in terms of genders (t=2.55, df=179, p=.012; boys: M=3.78, SD=.94; girls: M=3.40, SD=.84) and grade levels (t=2.42, df=179, p=.016; lower: M=3.85, SD=.83; upper: M=3.52, SD=.97), with higher scores of boy students and students in the lower primary group. According to the analysis, boy students were more confident in mathematics than girl students, as well as students in lower primary group showed more confidence in mathematics than those in upper primary group. Besides, no statistical significance was detected in mathematics expectancy-value beliefs, regardless of gender or grade level.

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Discussion

Discussion on Students' STEM Domain-specific Self-efficacy and Expectancy-value Beliefs

Given that most studies have concentrated in assessing students' overall STEM attitudes or the attitudes towards individual STEM discipline, the present research aimed to address some of the gap in the literature review by surveying primary school students' attitudes towards various STEM domains including science, mathematics, and engineering/technology. The results suggest that there is no significant effect not only on overall STEM attitudes but also on both the overall self-efficacy beliefs and overall expectancy-value beliefs among these three domains for primary school students. It has been mentioned above that little research has focused on STEM attitudes involving primary students, especially the lower graders (Zhou et al., 2019). In the literature database, there is a small part of studies focusing on middle school students' STEM attitudes (Wiebe et al., 2018; Unfried et al., 2014), while a large part of studies concentrate on measuring STEM attitudes of high school students and college students (Fraser, 1978; Simpkins et al., 2006; Speering & Rennie, 1996; Wang, 2012; 2013), possibly because the latter population is directly related to career choice after graduation. As revealed in previous studies, middle-school students considered science more difficult and unpleasant than other STEM domains (Mooney & Laubach, 2002). As well, another research found that middle school students had less career interest in engineering than mathematics and science (Lederman & Lederman, 2013). When comparing the present results of STEM domain-specific attitudes among primary school students with the related results in previous studies involved other graders, inconsistencies are found. It is important to note in the present research that students in primary school showed no difference on both the self-efficacy beliefs and expectancy-value beliefs. After further analyzing the career interest within the expectancy-value beliefs of mathematics (item 2: "When I am older, I might choose a job that uses math"), science (item 10: "I might choose a career in science"), and engineering/technology (item 26: "I believe I can be successful in engineering") , it is found that there is a significant effect ($F(2,540)=4.86$, $p=.008$, $\eta^2=.018$) among different STEM subjects in terms of career interest, with lower mean scores in math domain ($M=3.24$, $SD=1.24$) and science domain ($M=3.39$, $SD=1.36$), and a higher mean score in engineering/technology domain ($M=3.66$, $SD=1.23$). Post-hoc comparisons identified that student's career interest in engineering/technology domain is significantly higher than math domain and science domain. In other words, the engineering/technology area is the most popular among primary school students. The possible reason is that mathematics and science have long been regarded as the most fundamental disciplines, belonging to the accumulation and reserve of basic knowledge of other disciplines; engineering and technology, on the other hand, are highly technical fields, which are popular career choices in China.

From the perspective of the relationship between primary students' STEM self-efficacy and expectancy-value beliefs, there are different correlations between these two categories of STEM attitudes regarding to different STEM domains. Most encouraging, self-efficacy and expectancy-value beliefs are strongly correlated for engineering/technology domain. Moreover, a borderline strong correlation is shown between self-efficacy and expectancy-value beliefs for science domain. Note that a weaker correlation for mathematics suggests that students' mathematics expectancy-value is not strongly associated with their self-efficacy beliefs comparing to science and engineering/technology. In comparison, having been reported in the previous studies, there were moderate or even negative correlations among various variables of STEM attitudes (Johnpaul et al., 2018). Also, little relation has been found between self-efficacy and outcome expectancies in STEM-related domains (Maddux et al., 1986). However, based on the evidence of the positive correlations in the present research, it appears to have strong association between self-efficacy and expectancy-value in the science domain and engineering/technology domain in the primary population. It suggests that primary students are more likely to show expectancy-value in STEM fields if they have success in science or high self-efficacy in engineering/technology. These results provide evidence to support that STEM self-efficacy could be considered as a predictor of expectancy-value (Fouad & Smith, 1996) and it is in line with the viewpoint that having high expectancy-value beliefs is associated with the student's STEM academic success (Scott & Mallinckrodt, 2005), mainly in science and engineering/technology domains.

Discussion on the Differences of Students' STEM Domain-specific Attitudes in Terms of Genders or Grade Levels

As demonstrated in the previous research, there was no gender difference in students' overall STEM attitudes, but lower primary students exhibited better STEM attitudes than upper primary students (Zhou et al., 2019). The current research is a more progressive analysis of student performances on STEM domain-specific attitudes.

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As evident from the data, the grade difference in overall STEM attitude was contributed by grade difference in mathematics attitude, as primary students did not perform significant difference in both science attitude and engineering/technology attitude in terms of grade level. Consistently, the grade difference in overall self-efficacy beliefs was only caused by grade difference in mathematics self-efficacy beliefs. As well, although no significant difference was found between boy students and girl students in the overall STEM attitudes and the self-efficacy beliefs, gender difference still remained significant in mathematics overall attitudes and self-efficacy beliefs. This finding has been confirmed in the previous literature reviews (Eddy & Brownell, 2016; Cheryan et al., 2017).

However, as detailed earlier in the review of grade difference of various STEM disciplines attitudes, there was a general decline in science and engineering/technology attitudes as school progress for elder students (Ali et al., 2013; Potvin & Hasni, 2014a; Said et al., 2016), but mathematical attitude was relatively stable over time from upper primary school through higher grades (Unfried et al., 2014). It is worth noting that the present result in primary school population is inconsistent with, or even contrary to, the previous findings in the elder group. The underlying reason for the differences in STEM domain-specific attitudes may be the different teaching standards and assessment standards set by the Ministry of Education (MoE) for various STEM disciplines in primary school in China. Mathematics, along with Chinese and English, is positioned as the key discipline for teaching assessment at each school year and selection of outstanding students at the end of primary school. With the growth of grade, the increasing learning difficulty of mathematics might be directly associated to the decline of students' attitude of mathematics. Whereas, science and engineering/technology are relatively inferior disciplines, which are not included in the assessment and selection requirements from grade 1 through grade 6 in primary school. Therefore, students' attitudes towards science and engineering/technology are comparatively stable throughout the primary school years, as most students consider these disciplines to be less formal. In addition, gender had an impact on primary students' mathematics attitude but not their science and engineering/technology attitudes. The analysis of gender and grade differences in STEM domain-specific attitudes among primary students, which was not covered in the previous literature (Zhou et al., 2019; Unfried et al., 2014), may serve as an extension of the related research.

In the aspect of expectancy-value beliefs of STEM attitudes, it is found that primary students showed no different value in their expectancy beliefs across genders and grade levels in various STEM domains. Although lower and upper primary students showed different levels of self-efficacy beliefs, they did not differ in how much they value STEM domains. For genders, the present findings support the view of no gender differences in the expectancy-value levels of STEM (Eccles, 2009). Especially in mathematics, students' different senses of self-efficacy in terms of genders or grade levels did not influence their mathematics expectancy-value beliefs. However, it has been pointed out that boy students achieved higher level STEM expectancy-value beliefs as school progress (Watt et al., 2012; Yee & Eccles, 1988), Thus, it still needs to advocate that both self-efficacy and expectancy-value should deserve enough attention. It has been identified in most studies that the majority of students who major in STEM fields were directly affected by their growing STEM attitudes in late childhood and early adolescence (Wang 2013). The formation and cultivation of students' STEM self-efficacy and expectancy-value in the early school are associated to their later STEM degrees and STEM career aspirations.

Conclusions

The present analysis extends the previous research to gender and grade differences of students' STEM domain-specific attitudes including self-efficacy beliefs and expectancy-value beliefs in primary school years, and their correlations. On the one hand, the results suggest there are no significant effects among these three STEM domains in the overall attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs for primary students. The correlations between self-efficacy and expectancy-value are much stronger for the science domain and engineering/technology domain than the mathematics domain. On the other hand, no gender difference of the self-efficacy beliefs was detected except in the mathematics domain, and the result that lower primary students performed significantly better than upper primary students in the self-efficacy was also mainly contributed by the grade difference in the mathematics domain. However, no different expectancy-value beliefs existed across genders and grade levels in various STEM domains.

The present research reported some inconsistent results in the primary school year with those in the elder group. For example, it was addressed in the previous result that middle-school students considered science more difficult and unpleasant than other STEM domains, but no significant effect has been found among STEM domain-specific attitudes in primary school. For another example, it has been pointed out that boy students achieved higher

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level STEM expectancy-value beliefs as school progress, whereas the present finding showed no gender differences in STEM expectancy-value levels across genders for primary students. In addition, as detailed earlier in the review, there was a stable mathematical attitude and a general decline in science and engineering/technology attitudes as grade grow, while the grade difference of STEM attitudes was only caused by grade difference in mathematics attitude in the present research. Except for the underlying reasons towards the STEM educational reality in China that has been addressed above, more attention should be paid to the primary school population, especially the lower graders, because the period of primary school plays an essential role in their future choices of STEM courses and their interests in STEM careers.

Obviously, the present research also has its limitations. For example, the participants of this research were from a primary school in a province of China, and there is a lack of data collection in a wider scope to enhance the credibility of the research conclusions. In addition, the research did not track and record the performances of primary school students' STEM domain-specific self-efficacy and expectancy-value beliefs with the development of grade in a long-term way, therefore it is impossible to know how the STEM domain-specific attitudes of the same participant groups change with the increase of age. These limitations are expected to be fully explored and improved in future research.

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Declaration of Interest

Authors declare no competing interest.

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